THE FUNCTIONAL EXAMINATION OF THE EYE

J. HERBERT CLAIBORNE M.D.

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BY

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TO

DR. EMIL GRUENING

THIS BOOK IS DEDICATED IN GRATEFUL RECOLLECTION OF HIS EXCELLENT TEACHING

PREFACE

A philosopher has said that the task of an author is either to teach that which is not known or to recommend known truths by his manner of adorning them.

The author presents this book to the medical profession in the hope that he has put the known facts of a dry subject in a pleasing form.

INTRODUCTION.

THE importance of the functional examination in the determination of the refractive condition of the eye, and in the determination of the necessity for wearing glasses, cannot be over-estimated. For, whatever value may lie in keratoscopy, the ophthalmoscope, and the ophthalmometer, the fact remains that, in almost all cases, the functional examination is the crucial test. Moreover, the widespread conceit which exists that the fitting of glasses is an easy matter and lies within the intellectual capacity of most any one, warrants the publication of a monograph on this subject.

It is, indeed, difficult for any student to read the meagre descriptions of this examination that are found in text-books and retire with even a clear theoretical understanding of the subject. It is the purpose of the author to make the subject clear beyond peradventure for those who shall read these pages. It is his purpose, in short, to present it in such a way that a student may follow the lines laid down and perform the examination with scientific and mechanical accuracy without further instruction.

A fair success in teaching the subject for a number of years has led him to believe that he has won the right of presenting it. The ventilation of the subject of refraction, while it may be tedious, he believes to be essential for those who know little of the subject, or for those who have for-

gotten what they once knew. The author desires to call particular attention to the chapter on Presbyopia. To judge from the frequency with which glasses are prescribed for this condition by totally ignorant people, one might imagine it to be a very simple affair. As a matter of fact, it is the most difficult problem in refraction, and a thorough knowledge of it implies a thorough knowledge of all the anomalies of refraction.

The author also desires to call attention to the graphic formula or cross system, by which he indicates the refractive condition of the two principal meridians of the eye. He has reason to believe that by the use of this system he has succeeded in making students more readily understand the optical results of the combination of spherical with cylindrical glasses.

He has deemed it pertinent to add a chapter on the use of mydriatics, since, upon their use, the success in prescribing glasses in some cases largely depends. If a somewhat colloquial style has been adopted in the preparation of this monograph, the author would say that it has not been unintentional. He believes that the best way to catch and hold the attention of a student is to avoid a didactic style and stilted phrases. The book is a result of a course of lectures delivered for a number of years at the New York Polyclinic, and more particularly of a course in practical instruction given by the author in the College of Physicians and Surgeons, New York.

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CHAPTER I.

THE FACULTY OF VISION.

The faculty of vision is the physiological function of the eye. It is needless almost for me to tell you that this faculty does not, strictly speaking, lie within the eye. It lies, in fact, in the brain, and the most recent researches in the physiology of vision place the seat of this function in the cuneus of the occipital lobe of the cerebrum. The retina itself, then, has absolutely no power of perceiving the light that falls upon it. In what way the retina is influenced by light, what the change in its elements is when light falls upon it, has never been fully explained. It seems certain, however, that some change is wrought in it, and that this impression is conveyed through the nerve fibres of the optic nerve upward to the centre I have mentioned, and that there it is interpreted as light. You remember very well, I am sure, that the optic nerve itself, is incapable of receiving this impression, and you remember the familiar experiment in physiology by which you may find the "blind spot" in your eye. This blind spot corresponds to the entrance of the optic nerve, or the optic disc, as it is called. At the disc there are only optic nerve fibres, the outer layers of the retina being entirely absent. There is another spot of peculiar interest in the background of the eye, and that is the macula lutea or Yellow Spot of Sömmering. This is the spot of most distinct vision in the retina, and may be called the *seeing spot* as opposed to the

blind spot. You know that there are ten layers of the retina, but as we come to the edge of the yellow spot, all the layers cease except that of the rods and cones, and that when we reach the fovea centralis or *central pit*, nothing but the cones remain. This pit is the point of most distinct vision, and the light that falls into it is appreciated or seen most clearly by the visual centre in the cunens. From this pit outward the acuteness of vision diminishes until we reach the confines of the retina, the ora serrata, where the visual acuity is least. Inasmuch as there are only cones in the macula, and their number diminishes as we progress outward from the fovea, it is not an unreasonable assumption that the cones are the element in the retina in which that wondrous change is created that is interpreted by the cuneus as light. This, at least, is the dictum of the physiologists. It is consistent with these facts that there are found some birds whose retinæ consist entirely of cones and that they are possessed of wonderful power of vision. This amounts to their retinæ being composed of a number of yellow spots.

Outside of the yellow spot in man the rods predominate over the cones, but in birds the cones, as a rule, predominate. In some nocturnal birds, eminently the owl, only rods exist.

Vision may be divided into four kinds : Central, Peripheric, Distant and Near.

We have already dealt with central vision when we pointed out the faculty or function of the macula lutea. We have referred indirectly to the peripheric vision, when we said that the acuteness of vision diminished from the macula outward. The peripheric vision was doubtless given to animals primarily for the purpose of self-protection, and for the acquisition of prey. If you wish an illus-

tration of the value of peripheric vision, roll up in scroll form two sheets of music, and holding one in front of each eye, endeavor to cross some crowded thoroughfare. You would find that your field of vision would be restricted to the very small circle in front of each eye, and you would not progress far before you would be in imminent danger.

It is through the medium of peripheric vision that many arts can be practiced. It is through the medium of peripheric vision that we see many of the beauties of nature, for the world would indeed be but a small one were we able to see only those things whose images fall within the circle of the macula lutea. It is the peripheric vision which enables the individuals in an orchestra to see the baton of the leader beating time, while they keep their central vision upon the sheet of music before them. It is the peripheric vision which enables a pianist to see the movements of his fingers as they pass over the keyboard, while his central vision is cast upon the notes.

The distant vision is the faculty of the eye to recognize objects at a distance, and the near vision is the faculty of recognizing objects near. What these two terms, "distance" and "near" specially mean will be developed later. We shall proceed now to deal with the distant and central vision, leave the peripheric altogether, and shall take up the consideration of the near vision in the last lecture on refraction.

There are few people who see well in the distance who are not guilty of conceit about it, and it is not an unusual thing to see a number of people comparing their vision by looking at some distant object, such as a sign. It is obvious to you that however satisfactory this may be to them, it is not in any sense scientific, and that we must settle upon some degree of vision as that which is normal and

physiological, in order that we may be able to determine when the function is within and when without the limits of proper sight. Vision is a function which is more nearly even in man than any other function of the body. There is a certain power of vision which is the birthright of all men. There is the widest difference in the faculty of hearing in man, and no standard has been absolutely set down as normal. How much more true is this of taste and smell and feeling? Yet we can make a standard in the vision, and say that man must have vision equal to that or fall below the standard.

It is in a high degree probable that rays of light from two different sources or points must fall upon different cones in order to be seen as two things or objects; in other words, if rays from different objects were to fall upon one cone, the objects would appear as one. Now the smallest visual angle that can be perceived at the macula corresponds to 1′. So that our two objects must be separated by an interval of as much as or more than 1′ in order to be seen as two. If they are separated by an interval less than 1′, they will appear as one.

The visual angle is the angle included between the two lines drawn from the opposite sides of an object and passing through the nodal point; see figure 1. C.D. is an object, and the angle formed by it with reference to the eye is included between the lines Cc. and Dd. which meet at the nodal point N, and the angle C.N.D. is the angle under which the object C.D. is seen.

With the view of establishing some standard test by which the vision of all eyes can be measured, cards have been constructed upon which the letters of the alphabet are printed. We English-speaking people use the ordinary English letters of course, and these are serviceable for

almost all cases. Nevertheless, in clinical work it becomes sometimes necessary to have German characters at hand, because the middle class of Germans do not all recognize the

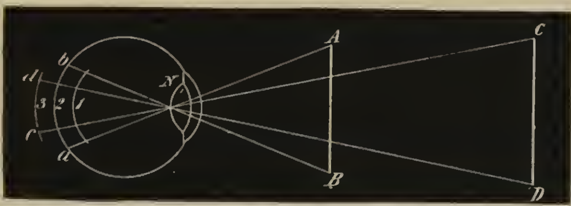


FIG. 1.

English letters. A card equally good for all is that on which figures are printed. For whatever may be the status of a person's learning in the matter of letters, there are a few people who know anything at all, who do not know the meaning of figures. The Arabic figures will probably be recognized by all the patients with whom you will come in contact. There is also a test card on which pot-hooks are printed. This seems to me to be of no value. It requires more knowledge to describe a pot-hook accurately than it does to recognize a letter or a figure. By way of using a universal system some one has suggested and had printed on the test card the hearts, diamonds, spades and clubs of playing cards. I have never seen anyone who has failed to recognize these.

By regarding the test card presented you will see that the letters diminish in size gradually from the top to the bottom of the card, and if you will look still more carefully, you will notice that over each line are inscribed certain Roman figures ; these figures indicate the distance at which the line over which they are written should be read by an eye possessed of the normal acuteness or acuity of

vision. The Roman figures indicate feet in this card. There are other cards in which the distance is indicated in metres. Now to those of us who have been accustomed to measure distance all our lives in feet and inches and lines, metres mean very little until we have translated them into feet and inches. At school you used to jump so many feet, not so many metres. It is immaterial, however, whether you use metres or feet, as you will see in a few minutes. The cards usually employed are those of Snellen, and letters are constructed upon the principle of the visual angle which is formed at the nodal point by the letters when situated at the distance indicated by the Roman figures over each line.

It has been stated that the objects must be separated by an angle of 1′ in order to be seen as two. Hence, the smallest retinal image which can be perceived at the macula corresponds to an angle of 1′ and each letter of the test card "is so made that when at its proper distance, each part of it is separated from the other by an interval equal to not less than the arc subtending an angle of 1′ at the nodal point," while the whole letter subtends an angle of 5′.

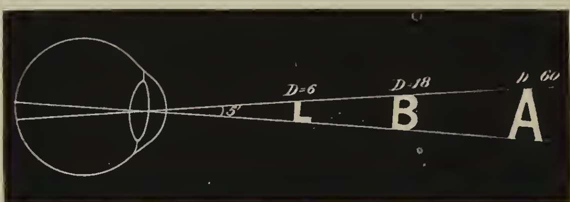


FIG. 2.

The letter L, for example, subtends an angle of 5′ at the nodal point at the distance of 6 metres (the equivalent of our 20 feet).

The letter A subtends an angle of 5′ at 60 m. distance, or 200 feet on our card.

It is clearly then a matter of no concern to us whether our patient recognizes the letter L at twenty feet or A at 200 feet. Each letter subtends at its respective distance the proper angle viz., 5′ at the proper point,—the nodal point, and the conditions for the normal acuity of vision, so far as the angle is concerncd, are fulfilled. But the brain must have the faculty of recognizing the letter. The angle would be formed, if the open eye of a dead man were placed in the track of rays emanating from the letters, but, of course, they would not be seen. Learn, therefore, immediately the difference between the optical condition and the function of the organ.

Although it may be the birthright of all men to be able to appreciate the angle of 5′, there may be those who have been cheated of it. In plain words, there are those who are not able to recognize the letter L at 20 feet, nor the letter A at 200 feet. Such people are said to have less than the normal acuity of vision. If you will cast your eye down the card we use you will observe that there are lines for 200 feet, 100 feet, 70 feet, 50, 40, 30 and 20 feet. So you will immediately see that it is unnecessary for us to place our card at 200 feet or any great distance. We may place it at 20 feet, as this card is placed, or we may place it at 15 or 10 feet. If the 20 line is read at 20 feet, or the 15 line at 15 feet, the 10 at 10 feet, we know that the patient has the normal acuity of vision because his brain has the power of knowing an angle of 5 minutes. Hence, the acuity can be reduced to a formula, and that formula amounts to the simple Rule of Three.

Suppose a man can read the 20 line at 20 feet, the proportion is this :

His vision ; Normal vision = 20:20 and this, you see, is reducible to the fraction $\frac{20}{20}$. Hence we would say $V = \frac{20}{20}$, and as the numerator and denominator of this fraction are equal, it is equal to the integer 1, which is perfection.

But suppose a man cannot read the 20 foot line at the distance of 20 feet, and can only read the 40 foot line at this distance, the proportion would be :

His vision ; Normal vision = 20:40

and this is equal to $\frac{20}{40}$ or $\frac{1}{2}$ of the normal vision. In like manner we would record $\frac{20}{200}$ when a man can only read the 200 line at 20 feet, and his acuity of vision wonld be $\frac{1}{10}$ of the normal. The meaning then of $\frac{20}{70}$, $\frac{20}{100}$, $\frac{20}{50}$, $\frac{20}{30}$ is clear.

Sometimes you meet people who can read further down the card than the 20 foot line at 20 feet. For example, a man may read the 10 foot line at 20 feet. Such a man would be said to have $V=\frac{20}{10}$ or twice the normal vision.

From all these facts we may draw this simple formula that $V=\frac{d}{D}$ in which d, the numerator, equals the distance of the patient from the card, and D, the denominator, equals the figuring over the line read.

CHAPTER II.

THE METHOD OF CONDUCTING THE EXAMINATION.

It now becomes necessary for you to know how this examination is conducted. This is a very important point, and it is the simplest.

In the first place adopt a routine. Hang or place the test card in a good light and place the chair of the patient preferably at the distance of 20 feet. The reason of this will be apparent in the next lecture. Let the light be behind the patient if possible, at any rate, to the side.

Examine the right eye first. The left eye must be covered, and this may be done in several ways. You yourself may hold a card in front of it, but you soon will get tired; or the patient may hold a card in front of it, but he will get tired. It is best to put on the patient a pair of spectacle frames for testing the eyes, such as you will find in the test case, and slip into the left side of the frame the opaque metal disc you will find in the case. In this way both yourself and the patient are relieved from work. This is a decided advantage in nervous or hysterical patients. Now tell the patient to read the card from above downward carefully. You might specify from left to right, for many stupid people will read a letter on each line in a vertical series. I have even known some who attempted to pronounce words which they supposed the letters are intended to spell. When the lowest line possible has been read record it mentally or otherwise, preferably on piece of

paper, and indicate that it is the vision of the right eye. Then uncover the left eye and cover the right one with the disc. Tell the patient now to read with the left eye as far as possible. Then record that as the vision of the left eye. This may be done in several ways. You may write it out in full if you wish, but the formula is more economical.

You may write R.E.V., which means right eye vision, or R.V., or R. You may use the Latin abbreviations, if you wish, O.D.V., which means *oculi dextri visio*; in like manner you may write L.E.V., L.V., or L., or *oculi sinistri visio,* for the vision of the left eye, for example:

$$\text{O.D.V.} = \tfrac{20}{20};$$
$$\text{O.S.V.} = \tfrac{20}{30};$$

Always use the equality marks, the periods after the abbreviations, and the semicolon after the fraction. The semicolon indicates that something is to follow, and what that is you will find out in the next lecture.

Patients are apt to close the covered eye. Advise them to keep it open; it is more comfortable to do so, and there is certainly no necessity of closing it when the opaque disc is used. By no means allow the patient to close the eye by pressing with the hand. If this is done, the vision of that eye is obscured for some seconds, on account of the temporary anaemia produced in the retinal vessels by the pressure. If the patient cannot read the first letter on the card at the distance at which he sits, bring the card nearer, or place him nearer the card. It is better for you to take the card and gradually approach the patient and mark the point at which he first sees the initial letter. When you have found this point there is no necessity of coming nearer. A man who cannot read the first letter at 20 feet

may be able to read it at 16 feet, if so, record his vision as $\frac{16}{200}$, by application of the rule as directed. It is clearly unnecessary to bring the card nearer than 16 feet if he can read the first letter at that distance.

Suppose a patient can read only the first letter at 1 foot his vision is of course, $\frac{1}{200}$. If he can read it only at 6 inches, his vision is $\frac{6}{200}$ inches by the rule. This, however, is an extremely vulgar fraction, and I would suggest that you simply write the fact and not the formula. Now the terms "fingers" and "200," are equivalent, and when a surgeon writes that a patient counts his fingers at 1 foot, he means $\frac{1}{200}$ by the card. The fingers are often used near-by, instead of the card. If the patient cannot count the fingers, the hand is moved upward and downward, outward and inward in front of the face. If the movements are correctly seen, it is stated that he sees "movements of the hand." If he is able only to recognize light from dark, or can recognize different degrees of luminosity, it is stated that he has "quantitative perception of light." Take care in making this test with the hands that the source of light is behind the patient. If the patient cannot tell the difference between day and night, his vision may be said to be O, i. e., he has no perception of light. In plain English you may state that he is stone blind.

CHAPTER III.

DESCRIPTION OF PRISMS, LENSES, AND THE TRIAL-CASE.

There are two kinds of lenses used in correcting the errors of refraction—spherical and cylindrical; these may be convex or concave. Before passing to the consideration of their properties, it is necessary to refer to the primary law of refraction of light and to the behaviour of rays of light that are incident to prisms, for upon the comprehension of these things depends the comprehension of spherical and cylindrical lenses.

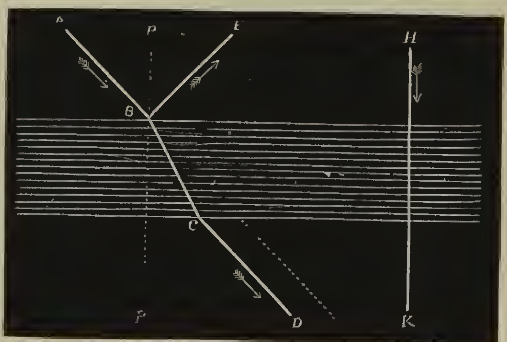


FIG. 3.

Rays of light in passing from a less dense into a denser medium are refracted toward a perpendicular drawn to the surface of the medium at the point of entrance; in passing from a denser to a less dense, they are refracted away from a perpendicular drawn to the surface of the medium at the

point of emergence. If the rays be at right angles to the surface separating the two media, they are not refracted at all.

At B the ray A B is refracted toward the perpendicular P P. At C the ray B D is refracted away from the perpendicular P P. The ray H K falling at a right angle to the surface of the medium, is not refracted.

In Fig. 3, the sides of the refracting medium are parallel, but in the case of a prism the surfaces are not parallel, and a ray can therefore be perpendicular to one surface only at a time. A ray that falls on a prism is refracted, and the deviation must be toward the base.

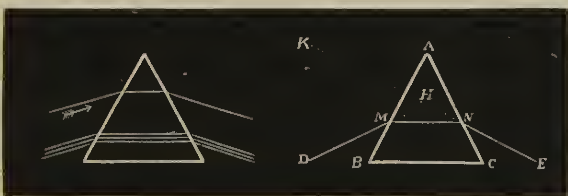


FIG. 4.

The ray D M falling upon a prism, is bent in the direction M N; at N it is again bent, so that an observer, catching the ray at E, would receive it as if it came from K.

Spherical convex and concave lenses may be regarded as being composed of prisms; the former with their bases, the latter with their apices, opposed. Since rays in passing through a prism are refracted towards its base, we can readily comprehend the fact that convex lenses cause convergence, and concave lenses divergence of rays.

A line which passes through the centre of a lens (optical centre) at right angles to the surfaces of the lens, is

called the *principal axis.* A ray passing through this axis is not refracted.

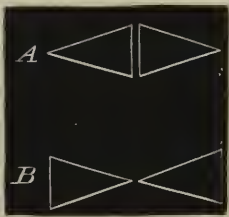


FIG. 5.

The ray B strikes the lens L at a right angle to its surface, and pursues a straight course to the point H. The ray A strikes the lens L obliquely at D, and is refracted

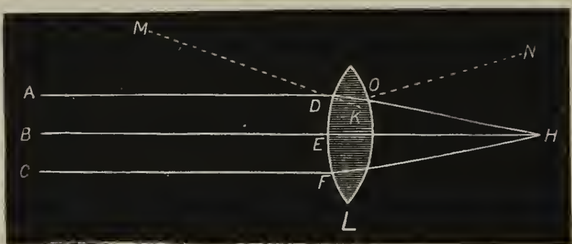


FIG. 6.

toward a perpendicular to the surface of the lens at that point, as shown by the dotted line M K. On leaving the lens at O, the ray is refracted away from the perpendicular N O, and meets the central ray B at the point H. The ray C in like manner meets the other rays at H.

Parallel rays then passing through a biconvex lens, are rendered convergent.

The ray B strikes the lens L at right angle, and is not refracted. The ray A strikes the lens L obliquely at D, and is refracted toward the perpendicular, G H. On emerg-

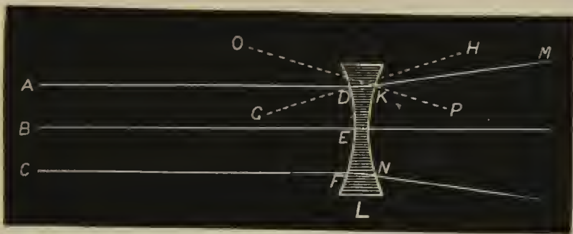


FIG. 7.

ing from the lens at K, it is bent away from the perpendicular O P in the direction K M. The like takes place with the ray C.

Parallel rays then passing through a bi-concave lens are rendered divergent.

All rays that do not pass through the principal axis are refracted. Those rays that pass through the optical centre, but not through the principal axis, are termed *secondary rays.*

FIG. 8.

They do undergo refraction, but in thin lenses it is so slight that they are assumed to pass in a straight line.

Parallel rays passing through a convex lens (L) are brought to a focus (A) at a certain fixed distance from the optical centre of the lens. Such a point is called the *principal focus* of the lens, and the distance of this point from the optical centre of the lens is called the *focal distance* of the lens.

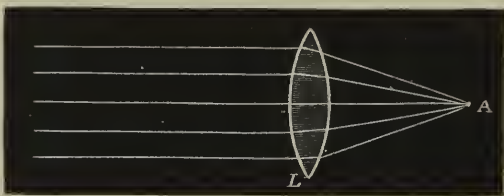


FIG. 9.

If parallel rays, passing through a concave lens be rendered divergent, the focus must be a virtual, negative one, situated on the same side of the lens as the object from which the rays proceed. If the divergent rays in Fig. 10 below, be continued backward, they will meet at F, the *principal focus*.

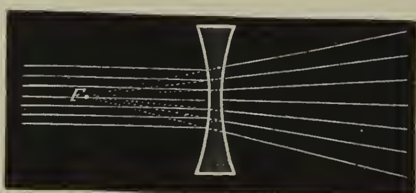
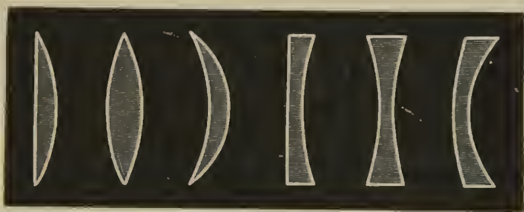


FIG. 10.

Spherical lenses may be plano-convex (Fig. 11, 1), that is, having one surface plane and the other convex; double convex (Fig. 11, 2) having both surfaces convex with the

same radius of curvature to both; converging concavo-convex (Fig. 11, 3) having one surface concave and the other convex, with the predominance of the latter, the so-called *positive meniscus;* plano-concave (Fig. 11, 4) double or bi-concave (Fig. 11, 5); diverging concavo-convex (Fig. 11, 6) with predominance of the concavity, the *negative meniscus.*



1 2 3 4 5 6

FIG. 11.

Cylindrical glasses are segments of cylinders. If we describe a circle on the outer side of an upright solid glass cylinder, the portion included within the circle will represent the surface of a convex cylindrical glass. The transverse diameter will have the greater radius of curvature, the vertical meridian which corresponds to the axis of the cylinder will be plane.

If we describe a circle on the inner side of an upright hollow glass cylinder, the portion included within the circle will represent the surface of a concave cylindrical glass. The transverse diameter will have the greater radius of curvature, the vertical, which corresponds to the axis of the cylinder, will be plane.

Such glasses, therefore, refract only those rays which are at right angles to their axis.

Cylindrical glasses are usually made plano-convex and plano-concave, and parallel rays passing through them at

right angles to the axis are rendered convergent or divergent respectively.

The axes of cylindrical glasses are often indicated by ground lines, one on either side of the lens or by the glass being ground rough on either side, so that the edges of the ground portion are parallel with the axis.

There are two systems of numbering lenses, one is the inch system and the other the metric system. For the former the convex lens, which brings parallel rays of light to a focus one inch from its optical centre, is taken as the standard for convex, spherical, and cylindrical glasses. Such a glass is called a convex No. 1. The convex lens which brings parallel rays of light to a focus at two inches from its optical centre is called a convex No. 2, and so on. The strength of a convex number two is obviously one-half that of a number one, and the strength of a number three obviously one-third that of a number one. Hence the strength of lenses is inversely as their focal distances, and the strength is expressed in the form of a vulgar fraction, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{30}$, $\frac{1}{80}$, etc.

The concave lens which gives to parallel rays such a divergence that, if prolonged backward, they will meet one inch from the optical centre of the lens, is taken as the standard for concave, spherical and cylindrical lenses. Such a lens is called a concave number one. A concave number two lens would give parallel rays such a divergence that, if prolonged backward, they would meet two inches from the optical centre of the lens. The strength of the latter is obviously one-half that of the former. Convex glasses are writen with the algebraic plus sign before them: $+\frac{1}{2}$, $+\frac{1}{30}$, $+\frac{1}{60}$, etc. Concave glasses are written with the algebraic minus sign before them: $-\frac{1}{10}$, $-\frac{1}{12}$, $-\frac{1}{80}$, etc. The plus and minus sign obtain also in recording convex

and concave cylindrical glasses. The standard or unit of the metric system is a lens of one metre focal distance; this is called a dioptry.

In some respects the dioptric system is preferable. It is certainly more commonly employed. The use of the vulgar fractions gave rise to much trouble in the handling of the common denominators. Moreover, the English and French inch differ slightly in length. In the metric system then we deal with integers and decimal fractions. D. is the abbreviation for dioptry. Thus +1 D. +2 D. —3 D., etc. In fractions we write thus: +1.5 D. —2.25 D. +3.75, +.25 D. +.50 D.

This simplifies matters a good deal.

It is necessary for you to know how to reduce the inch system to the dioptric system and the reverse. The English metre is 39+ inches, the French 37. For the sake of convenience we regard 39+ as 40 and 37 as 36. Of course, you understand that the metre is a fixed distance, it is the inch of France and England that differs. The English inch is shorter than the French, for it takes 39+ English inches and 37 French inches to make the metre.

Let us accept $\frac{1}{36}$ as the equivalent of 1 D.

1 D. $=\frac{1}{36}$.

2 D. $=\frac{2}{36}=\frac{1}{18}$.

3 D. $=\frac{3}{36}=\frac{1}{12}$.

4 D. $=\frac{4}{36}=\frac{1}{9}$.

.50 D. $=\frac{1}{36}\times\frac{1}{2}=\frac{1}{72}$.

.75 D. $=\frac{1}{36}\times\frac{3}{4}=\frac{3}{144}=\frac{1}{48}$.

.25 D. $=\frac{1}{36}\times\frac{1}{4}=\frac{1}{144}$.

Then

$$1.50\text{ D.}=\frac{1}{36}+\frac{1}{72}=\frac{3}{72}=\frac{1}{24}.$$
$$1.25\text{ D.}=\frac{1}{36}+\frac{1}{144}=\frac{5}{144}=\frac{1}{29}+=\frac{1}{30}.$$
$$1.75\text{ D.}=\frac{1}{36}+\frac{1}{48}=\frac{7}{144}=\frac{1}{20}.$$

To get the value of the dioptres in the inch system, multiply $\frac{1}{36}$ or $\frac{1}{40}$ by the number of dioptries.

The reduction of the inch system to the dioptry is equally simple:

$$\frac{1}{36}\times 36=\frac{36}{36}=1\text{ D.}$$
$$\frac{1}{18}\times 36=\frac{36}{18}=2\text{ D.}$$
$$\frac{1}{12}\times 36=\frac{36}{12}=3\text{ D.}$$
$$\frac{1}{9}\times 36=\frac{36}{9}=4\text{ D.}$$
$$\frac{1}{72}\times 36=\frac{36}{72}=.50\text{ D.}$$
$$\frac{1}{144}\times 36=\frac{36}{144}=.25\text{ D.}$$
$$\frac{1}{48}\times 36=\frac{36}{48}=.75\text{ D.}$$
$$\frac{1}{24}\times 36=\frac{36}{24}=1.5\text{ D.}$$

To reduce the inch system to dioptres, multiply the numerator of the vulgar fraction by 36 or 40.

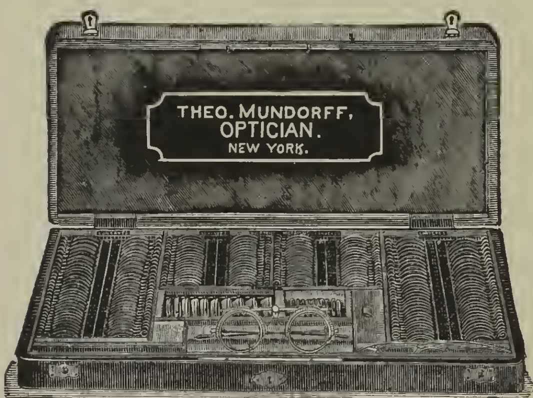


Fig. 12.

Fortunately, our test cases are so arranged that you are not under the necessity of making this reduction. It is done for you and recorded under your eyes.

The test case (see Fig. 12) contains convex and concave and cylindrical glasses; on the left are the concave glasses, on the right the convex. In the centre are the cylinders. The concave glasses are usually rimmed with brass, the convex with nickel. The same thing applies to the concave and convex cylinders. There are two of each set, and between each row is recorded the number of each glass in inches and dioptries, so that you can write either you choose. The smallest number, .25 D., is usually placed at the bottom of the column, nearest to you. There are not as many cylinders as there are spherical glasses.

There are usually two pairs of spectacle frames in the case, with an opaque disc for insertion in the frame to cover one eye while the other is under examination.

There are also prismatic glasses in the test case, but you do not concern yourself with them in the functional examination.

CHAPTER IV.

THE REFRACTION OF THE EYE.

The eye-ball may be considered an imperfect sphere, composed externally of the sclera of and the cornea. The cornea is a segment, in rough terms, of a smaller sphere, and is inserted in the anterior aspect of the sclera. It is the window through which the rays of light pass into the interior of the eye.

Within the eye are found, from before backward, the aqueous humor, the crystalline lens and the vitreous humor.

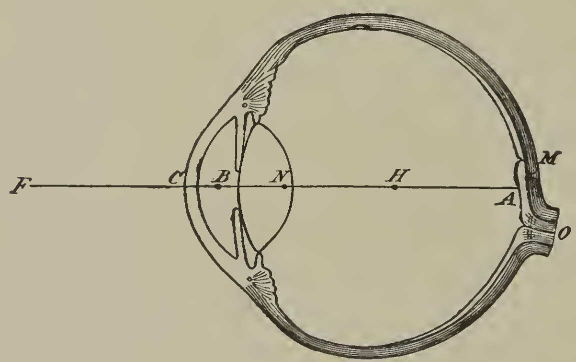


FIG. 13.

mor. At the posterior pole lies the retina, spread out upon the choroid, which latter, in its turn, is spread out on the sclera. The eye is indeed a photographic camera, and may be called a camera obscura in view of the dark pigment of the choroidal coat. This choroidal coat is in-

tended to absorb the rays of light, and keep them from being reflected about within the eye. Albinos do not possess this pigment, hence they are dazzled by light.

There are three kinds of eyes:

1. Emmetropic eyes;
2. Hypermetropic eyes or hyperopic eyes;
3. Myopic eyes.

The three conditions are called emmetropia, hypermetropia or hyperopia, myopia. The emmetropic eye is the natural eye, and is about $\frac{9}{10}$ of an inch in length—23 mm., if you wish it in the fractions of a metre. The other two eyes differ only in that one is longer and the other shorter

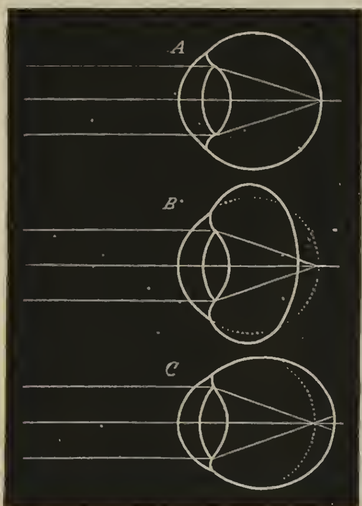


FIG. 14.

than the emmetropic eye. The hypermetropic or hyperopic eye is shorter than $\frac{9}{10}$ of an inch, and the myopic eye longer than $\frac{9}{10}$ of an inch.

A represents the emmetropic eye, B the hyperopic, and C the myopic eye.

The names can hardly be said to be well-chosen, as you will soon see.

The first, emmetropia, is derived from the Greek, meaning *within the measure of vision.* The second, hypermetropia or hyperopia, mean respectively *over the measure of vision* or *over-vision,* while the third is a distinct anomaly, meaning—well, it is difficult to say what. The fact is, the word myopia is derived from the Greek word μύειν, to close the eyes, and ὤψ, the eye. Myopes, when they do not use their proper correcting glasses, squeeze the lids together for the purpose of seeing better, and this habit has given them the name of myope, *i. e.*, one who sees with the eyes half closed. You have all doubtless observed this in myopes. In like manner, emmetropic persons are called emmetropes, and there is no equivalent in the English language for this term—we are condemned to the Greek. Hyperopic people are called hyperopes or hypermetropes; but for the terms hyperopia and myopia, English equivalents exist. Hyperopia is *far or long sight,* and myopia is *short or near sight.* Observe, now, the curious antithesis which has worked itself out—the short eye, the hyperopic eye, is the long- or far-sighted eye; and the long eye, the myopic eye, is the short- or near-sighted eye. There is another term for myopia, a very good term, indeed, and for this reason it is never used, *viz.:* brachymetropia, which is a literal translation into Greek of "short sight."

It becomes necessary, now, to consider these three eyes from an optical standpoint. In order to do that, allow me a moment's digression. When rays of light start from the same luminous point, they are necessarily divergent, and they continue to be so until they have traversed the distance of

20 feet. At this distance and beyond it, they are practically parallel. They are, indeed, quite as parallel as those that arrive from infinity, and the rays therefore that come to us from the card situated on the wall 20 feet away, have the same optical value as those that arrive from a star or planet in the firmament. The distance of 20 feet, then, is considered infinite distance in ophthalmology, and it is ordinarily referred to as *distance*. Anything nearer than 20 feet, is referred to as being near.

An emmetropic eye may be described as an eye which, in a state of rest, focuses parallel rays of light upon the macula lutea. (See A, Fig. 14.) The parallel rays of light from a distant source are focused upon the retina by virtue of the refractive power of the media without an effort on the part of the eye. A hyperopic eye is an eye which, in a state of rest, causes parallel rays of light to be focused behind the macula lutea. It is hardly necessary for me to say to you that no focus is formed behind the eye since the rays do not pierce the coats; but, since the eye is shorter than it should be, the rays fall upon the retina in the act of convergence before they have formed a focus. See B, Fig. 14. A myopic eye is an eye which, in a state of rest, focuses parallel rays of light in the vitreous humor, *i. e.*, in front of the macula lutea, so that the rays of light which form a focus in the vitreous humor again diverge and fall upon the retina in a condition of divergence. See C, Fig. 14.

An emmetropic person will therefore see distant objects because a focus is formed on the macula; and this act is accompanied by no effort on the part of the possessor of this eye. It is not improbable that some of the pleasure derived from regarding distant landscapes, apart from the pleasing effect of the hues and tone of distance, is due to

3

the rest which the eye enjoys under these circumstances. Such an eye, looking into distance, is as much a mechanical instrument as the camera of a photographer.

Let us now turn our attention to the hyperopic eye. The rays do not form a focus on the retina, as you can see; such an eye, therefore, cannot see distant objects well. Instead of the points that make up a focus, *circles of diffusion* are formed, and for every point there is a circle. An imperfect, enlarged, and blurred image is formed on the retina, and the shorter the eye, the larger, more blurred and more imperfect the image. You are surprised to know that a far-sighted eye cannot see far! From the cut it is clear that it cannot see well in the distance, but it is a fact that it does see distant objects well. Just here it is necessary to digress once more. You are surely acquainted with the ciliary muscle; if you will refer once more to Fig. 13, you will see it just behind the root of the iris. This muscle runs round the eye, and depending from it is a ligament, called the ciliary ligament, one layer of which is attached to the anterior, and the other to the posterior, surface of the lens. The lens is elastic and resilient, and will readily swell if pressure be taken from it. Now this lens and muscle is in a condition of perfect repose when the emmetropic eye is in a state of rest, *i. e.*, is looking at distant objects, but when the gaze is turned upon near objects, a change takes place in this apparatus. The rays coming from near objects are not parallel, but are divergent, as you know, and the emmetropic eye in a state of rest can focus only parallel rays on the retina; hence, this rest must be abandoned if that eye has to see near objects. The brain gives the cue to the centres of the third nerve that the time has come for action, and tells them how much nerve force must be sent to the mus-

cle of accomodation to accomplish the purpose of clear vision. The ring-shaped muscle then acts, and, like all muscles, it shortens its origin upon its insertion. As that is done, the tension upon the anterior surface of the lens is relieved and the lens springs forward, thereby increasing its antero-posterior diameter and increasing its power of refraction. In this way the eye accommodates itself for

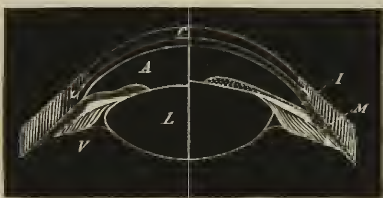


FIG. 15.

different distances inside of 20 feet, and the most beautiful thing about the function is that the brain always measures the distance accurately, and sends just the force necessary to do the work and no more. The act of accommodation belongs properly to vision within 20 feet. But we have seen that the unfortunate hyperope cannot see distant objects well on account of the shortness of his ball. The brain searching around for a means of forming a good focus, turns to the accommodation, and finds that, by the use of this function, a good focus can be formed, and its desire for clear, distant vision be satisfied. This is an iniquitous use of the muscle of accommodation, but it is persisted in. The hyperope then *does* see clearly in the distance, but he does so at the expense of a muscular action that is intended by nature only for the act of near vision. Whenever a law of nature is broken, retribution is inevitable, and the rupture of this law constitutes no exception. The hyperope pays

for his clear vision in headache, eyeache, nausea, vomiting, tumbling gait, and many other symptoms which are characterized as those of asthenopia or weak eyes. The hyperopic errors are by far the greatest cause of asthenopia in the errors of refraction.

I withdraw, then, the statement that the hyperope does not see well in the distance.

By referring to C, Fig. 14, you will perceive that a myopic eye cannot possibly see distant objects well, for the parallel rays are focused in the vitreous humor, and, having formed a focus, again diverge, so that they arrive at the retina in a condition of divergence. Circles of diffusion are formed on the retina instead of points, and for every point a circle is formed. The image of the distant objects, therefore, is blurred and enlarged. There is no remedy for this condition within the eye. Suppose the eye endeavors to remedy the defect by the act of accommodation. The refractive power of the eye will be increased, and so far from the eye seeing better, it will see worse, for the focus will be formed still further forward in the vitreous humor, and the circles of diffusion will be proportionately larger. The trust of the myope lies in the art of man. Pain is not so frequently caused by myopia as it is by hyperopia, and the reason is clear. The myopic eye has a dreamy look, in other words, a look which is an attribute of beauty. Myopic eyes often appear large, and this has, from immemorial time, been regarded as an attribute of beauty. The expression "ox-eyed," as applied to Juno, is familiar to many of you. This dreamy look has been termed the "myopic stare." There can be little doubt that myopia, to some extent, influences the mental qualities when it develops in early life. A boy who cannot see well in the distance is little likely to engage in field sports,

for not only would he be unsuccessful, but he would also be in danger of injury. Consequently he would be inclined to be a book-worm and studious, if he has brains and the proper disposition. If naturally stupid, he is apt to become a drone. The future of many a person could have been altered, if their refractive error had been corrected in youth. The world in which a myope lives is a narrow one, and the more myopic he is, the narrower it is. His powers of observation are limited, and his knowledge of the wide world corresponds.

CHAPTER V.

APPLICATION OF THE TEST CARD TO THE ERRORS OF REFRACTION.

It becomes necessary now for us to apply the test card, and what we have learned about the acuity of vision to the refraction of the eye. Let us take up each condition in its turn. The term emmetropia we have seen means *within the measure of vision.* Any eye, therefore, you would naturally assume, that has vision within the normal measure would be emmetropic. This is not true. You must learn for good that the term emmetropia refers by consent to the refraction of the eye and not to the function. So try to forget the etymological meaning of emmetropia. An emmetropic eye, we have seen, focuses parallel rays of light upon the retina without an effort of the accommodation. A man may be dead and have emmetropia or his optic nerve may be atrophic, so that he cannot tell light from darkness, and yet be emmetropic. Conversely, because a man has $\frac{20}{20}$ vision, it is not a necessary conclusion that he is emmetropic.

Hypermetropia means *beyond the measure of vision*, and you would infer from this that any man who can see more than $\frac{20}{20}$ is hyperopic. This also is not true. An emmetrope sometimes has the exceptional vision of $\frac{20}{15}$ or $\frac{20}{10}$. On the other hand, hyperopes naturally see farther than emmetropes, for their eyes are capable of recognizing a smaller visual angle than emmetropes. Yet a hyperope whose fundus and media are normal may not be able to see as much

as $\frac{20}{20}$. He may not have had that amount of acuity of vision by nature and there may be other reasons also. For example, his muscle of accommodation may have been paralyzed by atropine, or as a sequella of diphtheria or syphilis. Weakness from prolonged fever may interfere with his accommodation, or what is more natural, he may not be able to overcome the error through age. In any of these cases, a hyperope will not be able to see $\frac{20}{20}$, hence the term would appear to be an incorrect one.

A myope cannot see well in the distance, and hence, cannot see $\frac{20}{20}$. A man, however, who does not see $\frac{20}{20}$ need not be myopic, since we have just seen that he may be emmetropic with function diminished from disturbance with the perceptive apparatus or the media ; a hyperope too, may have less than $\frac{20}{20}$ vision, as we have seen. So that vision less than $\frac{20}{20}$ means nothing at all with reference to the refraction of an eye.

Let us sum up :

If a person reads $\frac{20}{20}$ on the card, i. e., has normal vision, you have learnt one negative fact, namely, that he cannot possibly be near-sighted. There remain two other conditions of refraction, emmetropia and hyperopia; he must possess one or the other of these.

If a person reads less than $\frac{20}{20}$, say $\frac{20}{50}$, you have learnt nothing whatsoever about his refractive condition. For he may be emmetropic with some disturbance in the fundus or media, or he may not have his birthright of $\frac{20}{20}$ vision ; he may be hyperopic with his accommodation weakened or eliminated ; or he may be myopic with an imperfect image on his retina by reason of his elongated eyeball.

Let us now make a practical demonstration of a few cases.

This patient whom I now present to you I have taken at random from among those on our benches. I shall ask him no questions, but will proceed to take the vision first of his right eye, and for that purpose I place this spectacle frame on his face and cover the left eye with the metal disc. He read $\frac{20}{20}$ as you see. Now I shall take the vision of his left eye; that also is $\frac{20}{20}$. What have we learned about this man? In the first place, he has normal acuity of vision, his eye is capable of appreciating an angle of 5′ accurately. So much for his function. But what have we learned about his refraction? Why this, that he cannot possibly be near-sighted, for he sees well at a distance. There are now only two other conditions of refraction left for us to consider, namely, hyperopia and emmetropia. To decide between these two, we must have recourse to our box of test glasses. I now pick out the weakest of the convex glasses, a +.25 D. or $\frac{1}{144}$ in the inch system, and place it before the right eye. He tells me, as you can hear, that he does not see so well through that glass as without it. The conclusion from this is inevitable; the man cannot be far-sighted, for if he had been, he would have been only too glad to have relaxed his accommodation and allowed me to represent it by my glass. He must, therefore, possess the only remaining condition of refraction, and that is emmetropia. The other eye gives the same result, as you see. I shall now ask the man what he complains of. He says "nothing whatever," and tells us that he brought his boy for treatment. He is not a patient. When the glass was put in front of his eye the parallel rays coming to him from distance were focused in front of his retina, so that he was rendered artificially near-sighted. Hence, as an emmetrope he saw worse than before, since he had *circles* and not points on his macula.

Let us take another patient. This boy complains of pain over his brows and headache in the occiput when he reads at school and when he studies at night.

Let us take his vision. With his right eye he sees $\frac{20}{20}$, and also with his left eye. You have now learnt one thing about his refraction, namely, that he cannot be near-sighted. So that two conditions remain for us to consider, hyperopia and emmetropia. This boy is apparently in the same condition as the man we have just examined, save that he has pain in his eyes and head on reading. Let us now place the weakest convex lens in front of his right eye, the .25 D. which I pick out of the case ; I now ask him to read the 20 line and he does it, as you see, easily. He also tells us that he sees it just as well. This boy has accepted a convex lens, and in this respect differs from his father whom we have just examined. What is the conclusion? He cannot be emmetropic like his father, for if he were, he would not see so well with as without the glass, for circles of diffusion instead of points would be formed on his retina. There is only one other possibility for us to consider and that is hyperopia. By exclusion then, the boy has hyperopia. When the convex glass is put in front of his eye he relaxes his accommodation to the extent of the value of the convex glass and allows me to represent his effort by my lens. He has just as good a focus as before and is saved work. Am I content to stop here? By no means. He may have still more hyperopia. Hence I now place the next strongest glass +.50 D. in front of his eye, and he tells me that is just as good, if not better, and, as you see, he still reads $\frac{20}{20}$. This boy then has as much as .50 D of hyperopia. I am not yet satisfied. I go further and find that he accepts +.75 D. and reads $\frac{20}{20}$. He says also that it gives him a feeling of rest. I go still further and place

$+1$ D. in the frame. He shakes his head and says he does not see quite so well. He may call off the letters for he has learned them by heart by this time, but he is intelligent enough to know that he does not see them so well. What have we accomplished here. We have measured the total amount of this boy's manifest hypermetropia, and that amount is .75 D. We continued to put glasses in front of his eye till he saw worse. That means that we formed a focus in front of his retina in the vitreous humor so that the focus on his retina or macula was imperfect. Hence the image of the letters was imperfect.

There is such a thing as an obstreperous muscle of accommodation. A muscle that will not relax its tension in hyperopia, but so far as you are concerned at present, a person who *will* not accept a convex lens, must be considered to be not far-sighted.

Let us draw our conclusion now from the study of this case. A person who sees $\frac{20}{20}$ cannot be near-sighted, and must be either hyperopic or emmetropic. If he sees equally well with a convex glass he cannot possibly be emmetropic, hence he must be hyperopic and the *strongest* convex glass through which he sees equally as well as without it, is the measure of his hyperopia.

We lay aside the class of cases in which the vision is as much as $\frac{20}{20}$ and take up those in which it is less. If a patient reads less than $\frac{20}{20}$, you have learned absolutely nothing about his refraction, and I hope you have not forgot the reasons for this statement. I repeat them. A person who reads less than $\frac{20}{20}$ may be emmetropic with some change in the fundus or media, or as a bare possibility, may not have the birthright of normal power of perception; he may be hyperopic with his accommodation limited or

eliminated; finally he may be myopic with an imperfect focus due to too great length of his eyeball.

I shall now pick out some cases illustrating these conditions. Here is an old man who can barely see in each eye as much as $\frac{20}{200}$; he has opacities in his lenses—has commencing cataract. Here is a middle-aged man who sees still less than $\frac{20}{200}$; he has partial atrophy of the optic nerve. Here is a little girl with dilated pupils, who has a high degree of hyperopia. She sees $\frac{20}{100}$ in each eye because her muscle of accommodation is paralyzed, and she has an imperfect focus in consequence. This is an old man who reads $\frac{20}{40}$, who is also hyperopic. No mydriatic has been put into his eyes, but he has an imperfect focus because he cannot use his muscle of accommodation. His muscular strength is going fast.

This woman with the prominent eyes is near-sighted and sees $\frac{20}{70}$ in each eye. She too has an imperfect focus because the rays meet in her vitreous chamber and fall on her retina in divergence.

The cause of the imperfect vision in the cases just shown, I have discovered by the use of the ophthalmoscope. But you must learn to settle on the cause by the functional method. Here is a case to which we will apply this method solely. The patient reads $\frac{20}{100}$ in each eye as you can see. Following the invariable rule, I place a plus .50 D. in front of his right eye. He says he sees worse. He cannot be hyperopic—he must be either emmetropic with disturbance in the media or fundus, or myopic. I now place a concave glass in front of the same eye and he tells me he can see no further—no better. He says the letters look a little sharper and smaller, that is all. The cause of his poor vision is not near-sight either. He must have

some disturbance in his media or fundus, and the great probability is that he is emmetropic.

This patient reads $\frac{20}{50}$ with each eye. The weakest convex glass makes him see worse. We exclude hyperopia. The weakest concave glass makes him see better. He must be near-sighted; he now reads $\frac{20}{40}$ with difficulty but he sees better. Shall we stop here? By no means. We increase the strength of the glass. He now sees $\frac{20}{30}$ with —.75 D.; with —1 D. he sees $\frac{20}{20}$. Are we content? By all means we should be. We wish no more than perfection, and that is expressed in $\frac{20}{20}$.

You perceive that the concave glass I placed in front of his eyes causes the rays to enter into his eye in the condition of divergence so that the focus that was first formed in the vitreous humor is then formed on the retina, and the circles of diffusion are supplanted by points. Hence, the retina has a perfect image, and as the function is unimpaired he sees $\frac{20}{20}$. You understand too that the first glass that causes $\frac{20}{20}$ vision is the measure of the myopia, for I might continue to use stronger glasses than is necessary and the patient still see $\frac{20}{20}$, since he would use his accommodation to overcome the excessive divergence of the rays. This would be equivalent to making him hyperopic. We do not wish to do that, we merely wish to render him emmetropic. Of course, we cannot always give $\frac{20}{20}$ with the proper correction, so that we may formulate our conclusions in myopia in this wise:

If a person sees better with a concave glass he is myopic, and the weakest concave glass with which he sees $\frac{20}{20}$, or gets the best possible vision, is the measure of his myopia.

There is here too such a thing as a spasm of the accommodation, so that an emmetropic person may appear

myopic, but so far as you are concerned in the functional method, the above conclusion is sound and good.

Let us now sum up in as few words as possible the propositions contained in what has been said at such great length.

If a person reads $\frac{20}{20}$, one thing has been learned in regard to his refraction—he cannot be near-sighted; he may be emmetropic or hyperopic. If he sees worse with the weakest convex lens in the case, he cannot be hyperopic, hence, he must be emmetropic. If he sees equally as well through the weakest convex lens, he cannot be emmetropic, hence, must be hyperopic, and the strongest convex glass through which he sees equally as well or better is the measure of his hyperopia.

Any one who sees equally as well or better through a convex glass must be hyperopic.

If a person reads less than $\frac{20}{20}$, nothing has been learned in regard to the refraction—he may be emmetropic with changes in media or fundus or he may not be possessed of the proper acuity of vision naturally; he may be hyperopic with the function of accommodation eliminated or impaired, whereby an imperfect image is formed on the retina; he may be myopic whereby an imperfect image is formed on the retina. If he sees worse through the weakest convex glass he cannot be hyperopic. If he sees better through the weakest convex glass he is hyperopic, and the strongest convex glass through which he sees best is the measure of his hyperopia. If he sees worse through the weakest convex glass and better through the weakest concave, he is myopic, and the weakest concave glass through which he sees best is the measure of his myopia.

If he sees worse through the weakest convex glass, and no better through the weakest concave, he is, in all

probability, emmetropic, with disturbance either in the media or fundus.

Cases and Formulæ.

Allow me to insist that you adopt a regular method of recording your results. You remember how I said the simple statement of vision was recorded. Let us record now the cases I have given you of E., H. and M.

Our first patient had this vision:

$$\text{R.E.V.} = \tfrac{20}{20};$$
$$\text{L.E.V.} = \tfrac{20}{20};$$

We found this patient to be emmetropic, so we simply write after the statement of the vision, E. thus:

$$\text{R.E.V.} = \tfrac{20}{20}; \ \text{E.}$$
$$\text{L.E.V.} = \tfrac{20}{20}; \ \text{E.}$$

Our next patient was hyperopic to the extent of .75 D., and his vision was $\frac{20}{20}$ in each eye. We record his case thus:

$$\text{R.E.V.} = \tfrac{20}{20}; \ \text{hm. .75 D.}$$
$$\text{L.E.V.} = \tfrac{20}{20}; \ \text{hm. .75 D.}$$

Hm., means manifest hyperopia. Another patient with hyperopia of 2 D. was unable to read $\frac{20}{20}$. We record his case thus:

$$\text{R.E.V.} = \tfrac{20}{50}; \ \tfrac{20}{20} \ \text{w.} + 2 \ \text{D.}$$
$$\text{L.E.V.} = \tfrac{20}{50}; \ \tfrac{20}{20} \ \text{w.} + 2 \ \text{D.}$$

His hyperopia is not said to be manifest since he failed to read $\frac{20}{20}$.

Our case of myopia is recorded in like manner:

R.E.V. $= \frac{20}{70}$; $\frac{20}{20}$ w. — 3 D.
L.E.V. $= \frac{20}{70}$; $\frac{20}{20}$ w. — 3 D.

The *w.* stands for *with*, and you observe that the two statements of vision are placed side by side for easy comparison, i. e., the vision before correction and the vision after correction.

Do not fail to adopt this method of recording your results. It is the plainest and simplest. There are many irregular ways of doing it which are clear to an expert, but nothing can be better than an unequivocally plain statement.

CHAPTER VI.

ASTIGMATISM.

We come now to discuss the matter of astigmatism. This subject is ordinarily regarded by students as extremely difficult to comprehend. Permit me to say that the difficulties lie on the surface and in the imagination. If you have followed me so far in the description of emmetropia, hypermetropia and myopia, and in the correction of the latter two, you will find no difficulty in following me in the exposition of astigmatism and its correction.

Astigmatism is the refractive condition of the eye in which a *point* cannot be recognized as such. It is seen as a line instead. The word is derived like so many terms in ophthalmology, from the Greek *α* privative—signifying *not* and *στίγμα* a point—not a point.

Let me state as the initial proposition in astigmatism, that there are but two meridians to the cornea, one being given, the other is at a right angle. So that if you accept 90° as the first, 180° is the other. If one meridian be 45°, the other is 135°, or if one be 75°, the other is 165°, etc. Remember the errors we have dealt with heretofore have been spherical errors, i. e., they have been errors of refraction that have been common to the two meridians of the eye.

We may refer to astigmatism also as a meridian error, since it belongs to one or the other meridian. When an eye is emmetropic both meridians of the cornea have the

same radius of curvature, and the eye from before backwards in each meridian is $\frac{9}{10}$ of an inch long. When an eye is spherically hypermetropic, each meridian has the same radius of curvature, but the length of the ball in each meridian is less than $\frac{9}{10}$ of an inch. When an eye is spherically myopic each meridian has the same radius of curvature, but the length of the ball in each meridian is more than $\frac{9}{10}$ of an inch.

When an eye is astigmatic, one meridian differs from the other in radius of curvature and in length from before backward.

We usually refer to the radius of curvature of the cornea when we speak of astigmatism, though there is such a thing as an astigmatism due to a prolongation of the eyeball at its posterior pole, as there probably is an astigmatism due to a badly shaped crystalline lens. Let us, however, keep our minds upon the cornea as the seat of astigmatism.

It will be very easy for you now to call off for me the various kinds of astigmatism.

1. Let us suppose a case in which the vertical meridian of the eye has the radius of curvature of emmetropia, and the horizontal meridian has the radius of curvature of hypermetropia; in other words, a cornea which in its vertical meridian is normally curved and in its horizontal meridian is curved too little, i. e., is slightly flattened. The condition is called

Simple hyperopic astigmatism.

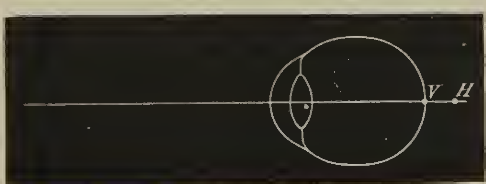


FIG. 16.

2. Let us suppose another case in which the horizontal meridian has the radius of curvature of emmetropia and the vertical meridian has the radius of curvature of myopia. In other words, an eye whose horizontal meridian is normally curved and whose vertical meridian is too sharply curved. The condition is called

Simple myopic astigmatism.

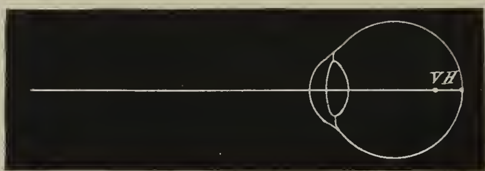


FIG. 17.

3. There is an eye, the vertical meridian of which is curved too little, and the horizontal meridian of which is curved still less. It is too flat in both meridians, and one, the horizontal, is flatter than the other, the vertical. Both meridians have the hypermetropic length from before backwards, but one is more hypermetropic than the other. The condition is called

Compound hyperopic astigmatism.

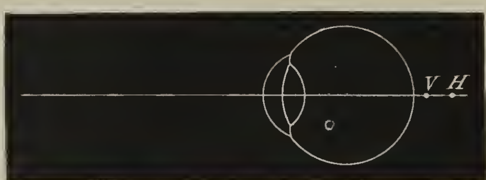


FIG. 18.

4. There is an eye, the horizontal meridian of which is curved too much, and the vertical meridian of which is curved still more. Both meridians have the myopic curve and length from before backwards, but one is more myopic than the other. The condition is called

Compound myopic astigmatism.

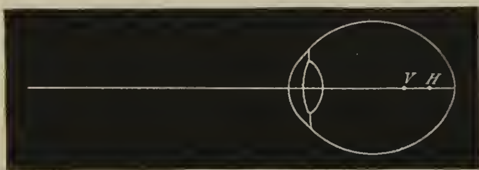


FIG. 19.

5. There is an eye, the horizontal meridian of which is less sharply curved, and the vertical meridian of which is more sharply curved than it ought to be. There is hypermetropia in the horizontal meridian and myopia in the vertical meridian. The condition is called

Mixed astigmatism.

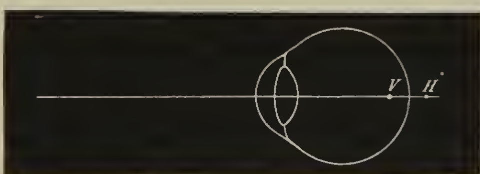


FIG. 20.

6. Occasionally the cornea of an eye may have scattered over it small opacities from old inflammation or from coal or foreign bodies which have lodged there. This condition is known as

Irregular corneal astigmatism.

Occasionally the lens is badly made, so that it differs in many places in refractive power. This is known as

Irregular lenticular astigmatism.

Irregular astigmatism, either corneal or lenticular, cannot be corrected by glasses or any other device.

You will now see that when once you have learned simple myopic and simple hyperopic astigmatism, you have learned all the forms of regular astigmatism. And you have already become convinced, I am sure, that what I said is true, namely, that astigmatism is the refractive conditions, E., H. and M., applied in combination to the two meridians of the eye.

Let us now once more sum up the various forms.

I. Regular astigatism.

1. Simple hyperopic astigmatism.
2. Simple myopic astigmatism.
3. Compound hyperopic astigmatism.
4. Compound myopic astigmatism.
5. Mixed astigmatism.

II. Irregular astigmatism.

(a) corneal.
(b) lenticular.

We will now take up the consideration of astigmatism from the standpoint of the behavior of the rays of light in each case. This necessitates a few preliminary remarks. From every luminous object rays of light proceed into space in every possible direction. From the planet Jupiter, for example, as it revolves in space, rays proceed in

all conceivable directions. From a point made by chalk on a blackboard, rays proceed in all directions that lie anterior to the plane of the board. They clearly cannot pass backward owing to the imperviousness of the board to light. But so far as the eye is concerned there are only two sets of rays,—one being given, the other lies at a right angle to it. If I hold up this pencil in front of you in a vertical position, you see it by virtue of the two meridians of the cornea, the vertical and horizontal. If I hold it at an angle of 45° to the horizon, you see it by virtue of the meridian which is 45° and of that which is 135°. If I hold it at the angle of 75°, you see it by virtue of the meridians of 75° and 165°.

Let me now hold the pencil vertical. From every luminous point on this pencil there proceed a set of vertical rays and a set of horizontal rays. The horizontal rays I indicate by the index and middle fingers between which I stick the pencil in the vertical position. These horizontal rays pass into your eye through the horizontal meridian, and are focused on your retina as a point. From the next luminous points above and below the first other horizontal rays proceed and pass through other planes of the horizontal meridian. Arriving at the retina they also form points, the one below and the other above the first point, so that there are now on your retinæ 3 points arranged in a vertical series, which is a line. The same thing takes place with reference to all the other luminous points on the pencil, and the result is that the vertical position of the pencil is indicated on your retinæ by a vertical line which consists of luminous points arranged in a vertical series. Suppose I turn the pencil to the horizontal position. From each luminous point on the pencil there proceeds a set of vertical rays and a set of horizontal rays. The vertical

rays I now indicate by the index and middle fingers between which the pencil is held horizontally. These vertical rays pass into the eye through the vertical meridian and are formed as points on the retina. From the next luminous points on the right and left other vertical rays proceed and passing into the eye through other planes of the vertical meridian are focused in a horizontal series. So that there are now on your retinæ 3 points arranged in a horizontal series, which is a line. The same thing takes place with reference to all the other luminous points, and the result is that the horizontal position of the pencil is indicated on your retinæ by a horizontal line which consists of a series of points arranged in a horizontal series.

The vertical position of the pencil then, is indicated by the horizontal rays that pass through the various planes of the horizontal meridian, and the horizontal position of the pencil is indicated by the vertical rays that pass through the various planes of the vertical meridian. In each position, however, both sets of rays are focused on the retina at the same time, so that the totality of the marks of the pencil is recognized, and it is distinguished from some other thing. Mark, however, that the image of a vertical object on the retina is vertical, and the image of a horizontal object on the retina is horizontal. Bear in mind also that there are many planes to each meridian.

1. Simple hyperopic astigmatism, see fig. 16.

In this case the rays of one meridian are brought to a point on the retina ; those of the other meridian are brought to a focus behind the retina.

2. Simple myopic astigmatism, see fig. 17.

In this case one set of rays are focused in front of the retina, the other on the retina.

3. Compound hyperopic astigmatism, see fig. 18.

In this case both sets of rays are focused behind the retina, one set being focused further behind it than the other.

4. Compound myopic astigmatism, see fig. 19.

Both sets are focused in front of the retina, one set being focused further in front than the other.

5. Mixed astigmatism, see fig. 20.

One set is focused in front of the retina, the other behind it.

We proceed now to the consideration of the correction of astigmatism. Before doing so, however, allow me to review what has been said with reference to cylindrical glasses.

Inasmuch as the error astigmatism, is an error of a meridian, it follows that the glass which corrects it must be a glass that refracts light in one meridian. Cylindrical glasses are used for this purpose. Cylindrical glasses reflect only those rays which are at a right angle to the axis. The axis is the plane surface which does not refract. If I hold a convex cylinder with its axis vertical, it is clear that only the horizontal rays are refracted; the vertical rays are unaffected, since they pass through a plane surface. If now, I turn the cylinder and make its axis horizontal, the vertical rays alone are refracted. The same thing is true of a concave cylinder.

Now a spherical convex glass is a representation of the human eye, and there are only two meridians to it as there are to the eye; one being given, the other is at a right angle. So that a convex spherical glass is composed of two cylinders with their axes at a right angle. If I can take two convex cylinders and place their axes at a angle and form a spherical focus, I have proved this point. Let us make this experiment: I take a convex cylinder of

6 D. and hold it with its axis vertical; the horizontal rays from our candle pass through the convex surface of the cylinder and form points in a vertical series, making a line of light. I turn it round at a right angle and hold the axis horizontal. The vertical rays now passing through the convex plane of the cylinders form points in a horizontal series and a horizontal line of light is seen. I take another cylinder of equal strength and place their axes at a right angle. This gives a convex surface horizontally and a convex surface vertically, so that both sets of rays are refracted. The result is, a perfect focus of the candle is formed. This is a typical illustration of the eye. When there is no astigmatism, the two meridians of the eye are equal in their refractive power and a perfect focus is formed. Suppose now I use a cylinder of 6 D. and couple that with a cylinder of 5 D., immediately an imperfect focus is formed on the blackboard, and you have before you the illustration of an astigmatic eye.

What I have said about convex cylinders applies to concave cylinders, with this exception, that no focus is formed by concave cylinders crossed, nor can any line of light be seen when the cylinders are used separately.

Let me impress this point upon you indelibly. The spherical eye is the equivalent of a spherical convex glass both of whose meridians are equal in radius of curvature and refractive power. If one meridian of the eye differs from the other in radius of curvature, there is astigmatism.

Let us now apply the cylinder to the various forms of astigmatism.

I. Regular astigmatism.

a. Simple hyperopic astigmatism.

In a very large majority of cases the erring meridian in this form is the horizontal. The vertical meridian has

the normal emmetropic curve, but the horizontal is flattened. It becomes necessary for us to so place the cylinder as that the refractive power of the horizontal meridian is increased.

Remember now that cylinders refract those rays that are at a right angle to the axis. We choose a convex cylinder, of course, since the error is hyperopic, and we place the axis vertical, thereby throwing the convex surface of the cylinder in the horizontal meridian in order to make up the deficiency there.

b. Simple myopic astigmatism.

In a very large majority of cases the erring meridian in this form is the vertical. The horizontal meridian has the normal curvature of emmetropia, while the vertical is too sharply curved. The cylinder must be so placed as that the refractive power of the vertical meridian be diminished. A concave cylinder must be used and the axis be placed horizontal in order to throw the concave surface of the cylinder vertical, to diminish the refraction in the vertical meridian.

c. Compound hyperopic astigmatism.

So far as the cylinder is concerned, the same rule applies to these cases as to simple hyperopic astigmatism. The cylinder has to be coupled with a spherical convex lens, and the axis of the cylinder, as a rule, is vertical. For the horizontal meridian is less curved than the vertical, and both are less curved than they should be.

d. Compound myopic astigmatism.

Both meridians are curved too sharply, and the vertical more sharply than the horizontal. So that the cylinder has to be coupled with a spherical concave glass, and the axis of the cylinder, as a rule, is horizontal.

e. Mixed astigmatism.

One meridian has the curvature of myopia and the other that of hyperopia.

Following out the rule in myopic astigmatism and in hyperopic astigmatism, for you remember that mixed astigmatism is a mixture of the two, the axis of the concave cylinder lies horizontal and that of the convex cylinder vertical. So that the cylinders are crossed at a right angle. It must be clear to you that neither cylinder interferes with the refraction of the other. For the rays that have passed through the horizontal refracting surface of the convex cylinder pass through the plane surface of the concave cylinder, and the diverging rays that have passed through the vertical refracting surface of the concave cylinder pass through the plane surface of the convex cylinder. Neither cylinder, therefore, interferes with the other. There are other ways of writing this combination, which will be shown later.

When the axes are as indicated above, namely, when the axis of the convex cylinder is vertical and that of the concave horizontal, the astigmatism is called *astigmatism with the rule.* When the reverse is the case, it is called *astigmatism against the rule.*

II. Irregular astigmatism.

There is no correction for this condition.

CHAPTER VII.

CASES OF ASTIGMATISM.

1. Simple hyperopic astigmatism.

A young woman, of delicate health and slight physique, who makes her living with her needle, complains that for several months her head has ached, particularly when she works or reads. The headache often reaches far into the night. She is unable to take much exercise, owing to her employment.

$$\text{O. D. V.} = \tfrac{20}{30} — ;$$
$$\text{O. S. V.} = \tfrac{20}{30} — ;$$

The errors she makes in reading the card are characteristic of astigmatism. She misses two or three letters in the 30 foot line, and scarcely gets one right in the 20 foot line. We suspect astigmatism from the start. But we first place +.50 D. S. before her eye. She states that makes it no better—brings out some letters that were unclear, but obscures others; —.50 D. makes her see worse. We now take +.50 D. cylinder and hold it, axis vertical, the usual position in As. H. She immediately sees better and expresses herself as pleased with the glass. But she is not yet able to read the 20 foot line perfectly. We try the next glass, +.75 D. cylinder, axis again vertical, and she reads the 20 foot line perfectly. Let us try the 1 D. cylinder now. She states that blurs the 20 foot line. We have

corrected her error, and it is $+.75$ D. cylinder axis $90°$. The same is found for her other eye.

We now proceed to write the result in a formula:

R. E. V.$=\frac{20}{30}$—; $\frac{20}{20}$ w.$+.75$ D. c. ax. $90°$.
L. E. V.$=\frac{20}{30}$—; $\frac{20}{20}$ w.$+.75$ D. c. ax. $90°$.

We prescribe:

℞ $+.75$ D. c. ax. $90°$.

This method of recording is intelligible beyond peradventure.

2. Simple myopic astigmatism.

This case is a student of the college, one of your number. He complains of his eyes blurring after using them for any length of time at reading. Has some headache. Eyes occasionally water. Cannot see the black-board and cuts well in the lecture-room. His eyes have the general look of being strained.

R. E. V.$=\frac{20}{40}$—;
L. E. V.$=\frac{20}{50}$—;

He also misses a letter or two before he arrives at the 40 foot line. We suspect astigmatism from that fact. Following the rule, we place $+.50$ D. S. in front of his eye. He sees worse. We place $-.50$ D. S. in front of it; he sees some letters better, but others worse. We try $+.50$ D. c. ax. $90°$; he sees worse still. We try $-.50$ D. c. ax. $180°$ and he immediately sees better. We are not content, for he has not yet reached $\frac{20}{20}$. We continue using concave cylinders, axis $180°$, till we arrive at -1.25 D. With that he reads $\frac{20}{20}$ clearly. We are content, and leave well enough alone. We find he requires -1.75 D. c. ax. $180°$ to read $\frac{20}{20}$ in the left eye.

We record the result thus :

R. E. V.$=\frac{20}{40}$— ; $\frac{20}{20}$ w. — 1.25 D. c. ax. 180°.
L. E. V.$=\frac{20}{50}$— ; $\frac{20}{20}$ w. — 1.75 D. c. ax. 180°.

The glass is prescribed thus :

℞ R. E. — 1.25 D. c. ax. 180°.
L. E. — 1.75 D. c. ax. 180°.

The optician attends to the rest.

3. Compound hyperopic astigmatism.

This patient is a young mechanic, who uses his eyes for near work constantly. You can see he is pale and not over-strong looking. He has had periodic headaches from childhood. During these attacks he becomes nauseated, throws up, has to go to bed and stay in a dark room for a day or two. Then he goes to work again until another attack. He is 28 years old.

R. E. V.$=\frac{20}{40}$— ;
L. E. V.$=\frac{20}{40}$— ;

With +.50 D. S. he sees equally as well as without the glass. He must be, to some extent, spherically hyperopic. We increase the strength of the convex spherical glass till we reach +2. D. He sees equally as well with this. +2.5 D. makes him see worse, so that we retreat to +2 D., with which he saw $\frac{20}{40}$— ; *i. e.*, quite as well as he saw without any glass. He must have 2 D. of spherical hypermetropia. But he does not yet see $\frac{20}{20}$, and our duty is to enable him to do that. We couple a convex cylinder +.50 D. with the +2 D., and, holding that combination, with the axis of the cylinder vertical before his right eye, we find he immediately reads further. We increase the

strength of the cylinder till we arrive at 1 D., when he reads $\frac{20}{20}$ without an error.

We find the same condition in the left eye. We record the result thus:

O. D. V.=$\frac{20}{40}$—; $\frac{20}{20}$ w.+2 D. S. ⁀‿ +1 D. c. ax. 90°.
O. S. V.=$\frac{20}{40}$—; $\frac{20}{20}$ w.+2 D. S. ⁀‿ +1 D. c. ax. 90°.

We may prescribe the glass thus:

℞ +2 D. S. ⁀‿ + 1 D. c. ax. 90°.

The optician knows from the formula that both eyes have the same correction. If the two eyes differed, we would write the prescription for them separately.

4. Compound myopic astigmatism.

This patient does not complain of very much headache or pain. He simply does not see well for reading or distance, and, saving his presence, you see his eyes have a far-away look and his whole countenance is apathetic.

O. D. V.=$\frac{20}{70}$—;
O. S. V.=$\frac{20}{70}$—;

Convex glasses make his vision worse. Concave glasses immediately improve it. We find that —2 D. is the weakest concave spherical glass with which the best vision is attained, but $\frac{20}{20}$ has not yet been reached. We now couple concave cylinders with the concave spherical and we find that with —1·50 D. cylinder, together with the —2 D. S., the vision in each eye is $\frac{20}{20}$, so that we write:

R. E. V.=$\frac{20}{70}$—; $\frac{20}{20}$ w. — 2 D. S. ⁀‿ — 1.5 D. c. ax. 180°.
L. E. V.=$\frac{20}{70}$—; $\frac{20}{20}$ w. — 2 D. S. ⁀‿ — 1.50 D. c. ax. 180°.

We prescribe thus:

— 2 D. S. ⁀‿ — 1.50 D. c. ax. 180°.

5. Mixed astigmatism.

This patient complains of constant, moderate headache, weariness of the eyes, the desire to close them to get rest, and the inability to see well near or in the distance.

R. E. V. $=\frac{20}{40}$— ;
L. E. V. $=\frac{20}{40}$— ;

We try first convex spherical glasses which fail to give any better vision. The same result attends the trial of concave spherical glasses. We next place a convex cylinder, .50 D., axis vertical, in front of his eye. He immediately sees better, and we continue to use stronger cylinders. With $+1$ D. cylinder he sees all the 40 foot line and makes one mistake only in the 30 foot line. With $+1.25$ D. cylinder he fails to see as well. We decide that he has, at least, As. H., and as we have excluded spherical hypermetropia, we turn to mixed astigmatism, as the possible explanation of his want of proper vision. We now couple $-.50$ D. c. ax. 180° with the $+1$ D. c. ax. 90°, and immediately he says he sees better. We continue to increase the strength of the concave cylinder till we arrive at -1 D. He now reads the 20 foot line perfectly, and expresses himself as satisfied. We conclude our patient has mixed astigmatism, and that it is *with the rule, i. e.*, the axis of the convex glass is vertical and that of the concave horizontal.

The same result is obtained in the left eye.

It is recorded thus :

R. E. V. $=\frac{20}{40}$—; $\frac{20}{20}$ w. $+1$ D. c. ax. 90° $\bigcirc$ -1 D. c. ax. 180°.
L. E. V. $=\frac{20}{40}$—; $\frac{20}{20}$ w. $+1$ D. c. ax. 90° $\bigcirc$ -1 D. c. ax. 180°.

There are three ways of writing this glass for the optician. First we may write it as it stands with the cylinder crossed :

$$+1 \text{ D. c. ax. } 90^\circ \genfrac{}{}{0pt}{}{\frown}{\smile} -1 \text{ D. c. ax. } 180^\circ.$$

Secondly, we may correct the As. H. by a spherical convex glass of 1 D. This will obviously double the error in the myopic meridian, so that we may also write it thus:

$$+1 \text{ D. S. } \genfrac{}{}{0pt}{}{\frown}{\smile} -2 \text{ D. c. ax. } 180^\circ.$$

Thirdly, we may correct the myopia by a spherical glass, and that will obviously double the error in hyperopic meridian, so that we may also write the prescription thus:

$$-1 \text{ D. s. } \genfrac{}{}{0pt}{}{\frown}{\smile} +2 \text{ D. c. ax. } 90^\circ.$$

Any one of these writings is correct. I would suggest, however, that you write it as you find the glasses in your hands, namely, with the cylinders crossed, and let the optician grind it his own way.

And now a word about the axis of astigmatism. I have spoken so far only of those cases of astigmatism in which the axis was 90° or 180°. It has, doubtless, occurred to you that the axis might lie at other points than these. It is possible for the axis of astigmatism to lie at any point in the circle of 360°. There are, however, beyond a question, "positions of preference." In a paper in the *N. Y. Medical Journal*, June 25 and July 2, 1892, entitled "The Axis of Astigmatism," I propounded the proposition that the axis of astigmatism does not occur at haphazard; that there are positions of preference in hyperopic and myopic astigmatism, and in their combinations.

Our spectacle frames, as you can see (Fig. 12), do not possess entire circles, but half circles. Sometimes the half circle is below, sometimes above, so that we number only 180° for each half circle. Now you may indicate the position of the axis of the glass in two ways, either by writing out the axis of the glass, such as 75°, 105°, 135°, etc.,

or by saying that the axis lies toward the nose or temple so many degrees, such as 20° or 15° or 45°; but you should take care to observe that the upper end of the axis is toward the nose or temple, for it must be plain to you that if the upper end of the axis is 45° toward the nose, the lower end must be 45° toward the temple. For my part, I always write the number of degrees without referring to nose or temple, and I think it much the best way. Inasmuch as we use semi-circles in the frames, either above or below, the figures are invariable. Observe the two spectacle frames, one above the other, Fig. 12.

In addition to the test-card, we sometimes use a figure called Snellen's Sun-rise, or a clock-face with lines radiating toward the various hours, such as in Fig. 21.

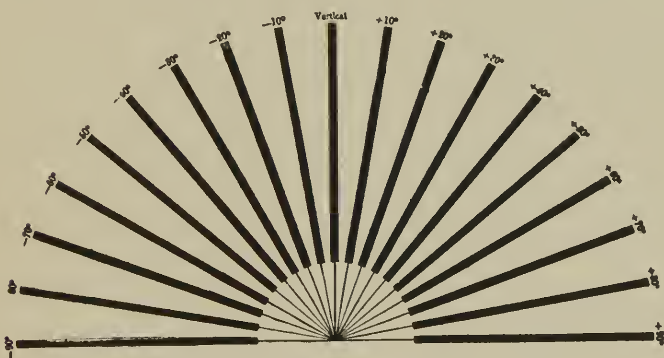


FIG. 21.

If astigmatism be present in a case, the various lines do not have the same degree of distinctness. Some are gray, while others are clear, or both are grayish, and some more gray or clear than others. If the cylinder or cylinders are properly applied, the lines appear equally clear.

I think these figures of value only in very slight degrees of astigmatism, such as that of .25 D. or .50 D. For greater errors the letters are sufficient, and, as a matter of fact, Snellen's Sun-rise or the clock-face is rarely used.

CHAPTER VIII.

PRESBYOPIA.

The first thing I wish you to learn in regard to the condition known as as presbyopia is that it is not an error of refraction. It is no error at all. It is a normal physiological condition to which every one comes if he lives long enough. The derivation of the word gives a clear insight into its meaning—πρέσβυς, an old man, and ὤψ, eye—the eye of an old man. And that is exactly what presbyopia is. But we must remember that it is his vision for near objects. It has nothing to do with his distant vision, strictly speaking. I promised you in the first lecture that I would take up the consideration of near central vision in this lecture, and I now proceed to do so.

Refer once more to the description of the act of accommodation.

You remember that the accommodative apparatus consisted of the lens, the muscle, and the ligament of Zinn. I said that the legitimate function of the accommodative apparatus was the adjusting of the refraction of the eye for different distances within 20 feet. I wish to lay particular stress upon that fact. That is why the act is called accommodation. It is accommodation of the pronounced sort to the possessor of an eye, and it enables the eye to accommodate itself for different distances.

The emmetropic eye you know is focused in a state of rest for parallel rays. If rays are divergent it is clear that

there must be an increased refractive power in the eye in order that they may be focused upon the retina accurately. This power lies in the accommodative apparatus. When an object is brought nearer than 20 feet to a person, his brain judges the distance and sends to the muscle of accommodation a stimulus which causes it to contract. In contracting it relieves the pressure made on the anterior surface of the lens by the anterior layer of the ligament of Zinn, and the lens, by virtue of its elasticity, springs forward, increasing its convexity and its antero-posterior diameter. The beautiful part of this act lies in this, that the muscle contracts just enough to form the focus accurately. In other words, when a man wishes to see an object 10 feet or 10 inches away, he focuses for the distance of 10 feet or 10 inches, and not for a less or greater distance. This faculty of accommodation has its limitations. It is greatest in early childhood. And this has been taken advantage of by tapestry manufacturers in Europe to set children to work, straining their eyes at a very early age. Owing to the fact that children are able to see smaller objects than grown people, they are enabled to use finer needles and do finer work. It has been estimated that the accommodation has reached its acme by ten years of age, and that thereafter it gradually decreases with advancing years till a certain age, when the condition of presbyopia is said to be present. Presbyopia then, is a condition in which there is a diminution in the power of the accommodative act in vision for near objects. This diminution is due partly to imperfect muscular action and to a loss of resiliency in the crystalline lens. When this has set in, a man may be said to have arrived at the acme of his years and strength. The road lies for him thereafter down-hill. The age of presbyopia in males lies somewhere between

40–45. It supervenes a little earlier in women. This must vary in a measure with a man's manner of life and employment. One who has lived an out-of-door life, free from impure air, who has kept regular hours, avoided excesses of all kinds, and who has not abused his eyes for reading and study or work, must retain the power of accommodation longer than one whose life has not been modelled on these lines. It would be an interesting thing to know when presbyopia supervenes, as an average, in a race of savages.

I have spoken of presbyopia with reference to any object that is nearer than 20 feet. But as a practical matter we treat of presbyopia with reference to reading.

In order that we may have a standard for this examination, as we had a standard for the distance examination, we take the various kinds of type that are used in printing books. They have been arranged in order, starting with the smallest and running to the largest. The card is known as Jaeger's Test Types, and we speak of a person's ability to read Jaeger No. 1 or Jaeger No. 2, etc. Jaeger No. 1, the diamond type, is taken as the standard. A normal adult should be able to read Jaeger No. 1 at 8 or 9 inches. Let us accept 8 inches. If he is unable to read it at this distance, but has to push the card further away, we say he lacks accommodation, in other words, he is presbyopic.

The nearest point at which a person can read Jaeger No. 1 is called the punctum proximum or near point. We may say that an adult's power of accommodation is the value of a plus 8 inch lens or 5 D., since he can read Jaeger No. 1 at eight inches. Conversely, we may say that a man has lost his entire power of accommodation when he has lost 5 D.

A table has been constructed showing how much accommodation is lost by the emmetropic eye at various ages :

40—	0 D.
45—	1 D.
50—	2 D.
55—	3 D.
60—	4 D.
65—	4.75 D.
70—	5.5 D.

You see, then, that a man may be said to have lcst his entire accommodation between the ages of 65–70, for at 70 he has lost 5.5 D., or more than the value of an 8 inch convex lens. But remember, we speak of his ability to read. He has not lost all his accommodation, and he probably never entirely loses it all.

The correction of presbyopia becomes an easy matter —to restore to a man that which he has lost. We must consider presbyopia with reference to E., M., H. and astigmatism. The list which has just been shown has been constructed for the emmetropic eye. And allow me just here to lay down for you this unalterable law, that every eye has to be restored to the condition of emmetropia before the proper presbyopic glass can be prescribed for it. The preceding examination which has been made clear to you, I hope, must be employed invariably before the examination for presbyopia. Let us take up a few cases.

Case 1.—Emmetropia and Presbyopia.

A gentlemen, of 45, complains that for the last 6 months his eyes have annoyed him in reading—particularly at night. They feel sandy ; he has a slight headache after prolonged reading. He has arrived at the age of

presbyopia, but before attempting to give him a glass, we discover the condition of his refraction. He reads $\frac{20}{20}$ in each eye and refuses the weakest convex glass. We find him to be emmetropic. We have plain sailing before us now. The list tell us that an emmetrope at 45 requires + 1 D. to bring his p.p. to 8 inches, or that he has lost + 1 D. of his accommodation. We restore to him what he has lost, and he reads, therefore, with his usual former comfort. If he lives long enough, he will take each correction for the succeeding years, as it is outlined in the list.

Case 2.—Hyperopia and Presbyopia.

This gentleman is 45 years of age. He has had more or less trouble with his eyes since boyhood, when he was subject to occasional headaches. For some time reading has been painful to his eyes, and it begins to dawn on him that he is getting old. He comes to find out whether it is true. By questioning him we find that he has been a student all his life. We proceed to carry out the distance examination first. We find that he reads $\frac{20}{20}$ with much difficulty and apparent strain. We also find that he accepts + 1 D. in each eye as the strongest possible glass. The man is hyperopic, and his age is that of presbyopia. If we are to give him a reading glass, we must certainly correct his hyperopia. We place + 1 D in front of each eye, and give him Jaeger's test types to read. He reads it with difficulty, as you see, at about 12 inches. He is presbyopic as well as hyperopic. We now add + 1 D to the + 1 D of his hyperopia. This makes + 2 D and we give him that glass. He reads Jaeger No. 1 now at 8 inches, and he can carry the book with ease out to 12 or 14 inches, so that we are content. We have given him a good range of accom-

modation, the distance between 8 and 14 inches, which is, 6 inches. So that you learn this fact from this case: the hyperopia must be added to the presbyopia.

$$H + Pr. = \text{Total correction.}$$

As he waxes in years, he will have to add the presbyopia for each age to the hyperopia which he has; at the age of 50 he will require 3 D.; at 55, 4 D., etc.

Case 3.—Myopia and Presbyopia.

Here is a patient whom I have selected from the clinic at large. He tells me he has arrived at the age of 46. I have asked him no questions, but inasmuch as he is 46, we may find a case of presbyopia.

He states that he has no difficulty in reading at all, although he is 46. He says he does not see very well in the distance; he thinks he is short-sighted. His vision in each eye is less than normal, and we find that —1 D. is the weakest glass with which he reads $\frac{20}{20}$. He is myopic to the extent of 1 D.

He is 46 years of age and by rights, if he were emmetropic, would accept +1 D. for reading. He does not need a convex glass to read with, because he has the value of +1 D. in the length of his eyeball. So that when he comes to read, he simply lifts his distance glasses to his brow or takes them off entirely.

Let us now give him the Jaeger Test Type. He reads Jaeger No. 1 at 8 inches with each, and has a good range of accommodation. Let us now put on his correction for distance, namely, —1 D. He is now emmetropic, and we give him Jaeger No. 1 to read once more. He is unable to do it at 8 inches. He reads it with difficulty at 10 to 14

inches. If we add to his distance correction, the correction for the presbyopia of an emmetropia, i. e., +1 D., the result is 0, for —1 D and +1 D. cancel each other.

If this man lives to the age of 50, he will require our help, for at 50 years an emmetrope requires +2 D., and as our patient has a myopia of 1 D only, he will require the difference between +2 D and —1 D., which is +1 D. At 55 he will require +3 D —1 D=2 D., etc. A man who has a myopia of 2 D will not require our services at 45 nor at 50. He will simply lift his distance glasses in order to read, but when he is 55 he will require help, and the glass he will need will be the difference between +3 D., an emmetrope's loss at 55, and —2 D., his myopia. He will then require +1 D. This method may be carried out in any case of myopia and presbyopia combined.

When myopia and presbyopia occur in a case, subtract the myopia from the amount of presbyopia that would exist in a case of emmetropia of the age of the myope.

Pr.—M:=Correction.

When a man has a myopia of as much as 3 D,= which is $\frac{1}{12}$, or 4 D= which is $\frac{1}{8}$, he probably never will require a plus glass at all for reading, for his far point lies at 12 or 8 inches, and he can read with great comfort at either point, because he does not need his accommodation at all. But suppose a man has a myopia of $\frac{1}{6}$, he will find it difficult to converge his visual lines for so short a distance. We must throw his far point further out. He has a myopia of 6 inches, i. e., his far point lies at 6 inches in front of his eye. We must throw that far point out to 12 inches, let us say for comfort. We give him $-\frac{1}{12}$ in order to do so, for $-\frac{1}{6}-\frac{1}{12}=-\frac{1}{12}$. A man with a myopia of $-\frac{1}{8}$ may not care to read at the distance of 8 inches. Let us

throw his far point out to 12 inches also. We give him a $-\frac{1}{24}$ for $\frac{1}{8}-\frac{1}{12}=-\frac{1}{24}$.

Astigmatism and Presbyopia.

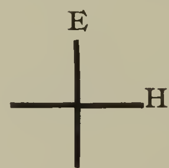
I will say in the beginning, for your comfort, that presbyopes rarely require or wish to have their astigmatism corrected when it is slight in degree. High degrees must, however, be noticed.

Case I. Simple hyperopic astigmatism and presbyopia.

We find that this patient has worn this glass for years.

$+1$ D c. ax. 90°.

If you will allow me to employ a system of crosses this matter can be made more graphically clear:



The E lies in the vertical meridian and the H in the horizontal.

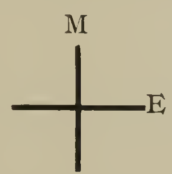
In other words, this glass has rendered him emmetropic. Since he is now emmetropic we will apply the rule as before for emmetropes. He is 45 years old, and is, therefore, at the presbyopic age. At this age our list tells us a man has lost $+1$ D. When we give him the test card to read he has to hold it out at a considerable distance, even while he has on his distance glasses. We now place over his spectacles our trial frames with $+1$ D in it and give him the card. He says that is better and more comfortable for his eyes. We have added $+1$ D to his astig-

matic correction, and that has to be ground as a compound lens by the optician. We prescribe for him thus:

℞ + 1 D s. $\overset{\frown}{\smile}$ + 1 D. c. ax. 90°.

Case 2. Simple myopic astigmatism and presbyopia.

Our patient has always worn — 1 D. c. ax. 180°. The graphic formula for the astigmatism is this is:



He is 45 years old, and commences to feel the need of help in reading. If he takes off his distance glasses he is astigmatic, and since he is 45 years old, let us place + 1 D. s. over his distance glasses. We then have this combination:

+ 1 D. s. $\overset{\frown}{\smile}$ — 1 D. c. ax. 180°.

This doubtless appears to you to be a curious combination. Let us see what it really amounts to. The — 1 D. c. ax. 180° neutralizes the + 1 D. s. in the vertical meridian, so that the covex spherical practically becomes a convex cylinder with its refracting surface horizontal. Now, as the patient is myopic naturally, to the extent of 1 D. in the vertical meridian, the combination really amounts to giving him an artificial myopia of 1 D horizontally. So that he has a myopia of 1 D. in each meridian, and as he is 45 years of age, he is in the position of a spherical myope of 1 D. The demands of his age have been satisfied. We may write this glass much more simply, thus:

$+1$ D. c. ax. 90°.

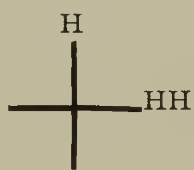
For this glass gives him $+1$ D. s. in his horizontal meridian and this with his natural myopia of 1 D. vertical, puts him practically in possession of $+1$ D. spherical.

You may write the glass either way. The optician will select his own way of grinding it.

Case 3. Compound hyperopic astigmatism and presbyopia.

In compound hyperopic astigmatism coupled with presbyopia, the presbyopic correction is simply to be added to the compound glass. This, of course, merely increases the spherical glass, the strength of the cylinder remaining the same.

Graphic formula for compound hyperopic astigmatism :



Case 4. Compound myopic astigmatism and presbyopia.

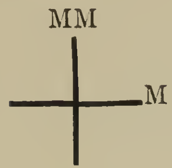
In this condition, the cylinder may be considered constant, and the simple myopia must be subtracted from the presbyopia.

Let us take a case of this, for it is more complicated than the preceding.

A man of 50 wears for distance,

-1 D. s. $\frown$ -1 D. c. ax. 180°.

The graphic formula for this condition of refraction is :



This combination renders him emmetropic. He is 50 years of age, and, as an emmetrope at that age requires +2 D, we add +2 D to the above formula:

$$-1 \text{ D. s.} \bigcirc +2 \text{ D. s.} \bigcirc -1 \text{ D. c. ax. } 180^\circ.$$

The result is

$$+1 \text{ D. s.} \bigcirc -1 \text{ D. c. ax. } 180^\circ.$$

Now a man with compound myopia

$$-1 \text{ D. s.} \bigcirc -1 \text{ D. c. ax. } 180^\circ.$$

has a myopia of 2 D. in the vertical meridian and 1 D. in the horizontal. As he is 50 years old, he requires 2 D. in each meridian according to the list, so that we prescribe:

$$+1 \text{ D. c. ax. } 90^\circ.$$

This gives him 2 D. of myopia in the horizontal and vertical meridians, and his demands are satisfied; e. g., graphically:

You have doubtless observed that we have corrected a case of simple myopic astigmatism, see case 2, and one of

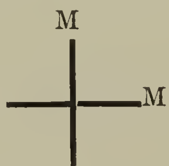
compound myopic astigmatism, with the same glass. The explanation lies in the spherical myopia of the latter case, and in the difference between the ages of the patient.

Let us take the case of a man of 45, with the correction,

$$-1 \text{ D. s.} \bigcirc -1 \text{ D. c. ax. } 180°.$$

He has a compound error, and we only need to correct the simple myopic astigmatism ; we thus leave him with 1 D. of myopia in each meridian, which is enough for him to read with. We give such a case,

$$-1 \text{ D. c. ax. } 180°.$$



Case 5. Mixed astigmatism and presbyopia.

A patient of 50 years has worn this correction,

$$+2 \text{ D. c. ax. } 90° \bigcirc -2 \text{ D. c. ax. } 180°.$$

This renders him emmetropic. If we put on his spectacles and ask him to read, he is unable to do so. We place $+2$ D s. over his spectacles and he reads with ease.

From our studies in mixed astigmatism you remember that there are 3 ways of writing the above formula: first, the way it is written above in crossed cylinders, secondly,

$$+2 \text{ D. s.} \bigcirc -4 \text{ D. c. ax. } 180^\circ$$

or thirdly,

$$-2 \text{ D. s.} \bigcirc +4 \text{ D. c. ax. } 90^\circ.$$

Now if to either of the last two we add +2 D, the presbyopic correction for a man of 50 years, we write:

$$+4 \text{ D. s.} \bigcirc -4 \text{ D. c. ax. } 180^\circ \text{ or}$$
$$+2 \text{ D. s.} \bigcirc -2 \text{ D. s.} \bigcirc +4 \text{ D. c. ax. } 90^\circ.$$

This latter formula is equal to

$$+4 \text{ D. c. ax. } 90^\circ.$$

But the great probability is that the optician prefers to grind the second formula, i. e., a concave cylinder of 4 D. on a spherical plus glass of 4 D. Under either circumstance, the resultant value is

$$+4 \text{ D. c. ax. } 90^\circ.$$

The vertical meridian now has its natural myopia of 2 D., and the hypermetropia of 2 D of the horizontal meridian has not only been corrected, but 2 D. more added to it. Hence, each meridian has 2 D., and the demands of the patient's age have been satisfied.

Although it is apparently easy to correct presbyopia, the fact is that failure is more common in its correction than in errors of refraction. The cause lies in this that presbyopia is a matter of function. The muscle of accom-

modation has not always the same innervation. This differs with time and circumstance. In youth there is a regular tone to the muscle as a rule, but such is not the case in presbyopia. A patient who is satisfied with one correction one day, will return the next and complain that the glasses are unsatisfactory. This is particularly the case with females. They are not able to analyze their sensations as accurately as men.

And now, a few words of common sense about the correction of presbyopia.

Do not stick to any iron-clad rule in giving a glass. Sometimes a stronger and sometimes a weaker glass than apparently the correct one, is accepted.

I have stated that every adult, not presbyopic, ought to be able to read Jaeger No. 1 at 8 inches. It is not improbable that the great majority of adults can do this for a few seconds, but there are very few that can keep it up longer than a minute or two. Most people read at the distance of 10 or 12 inches, and books are usually printed in type of the size of Jaeger No. 4 or 5, at least; more frequently in type of the size of Nos. 6 or 7. So that the test when made with Jaeger No. 1 is a test of supreme capacity, not of ordinary working power. Try always to give your patient as long a "range of accommodation" as possible, that is, to give a glass that gives the greatest possible distance between the nearest point and the farthest point of distinct vision.

After you have made your estimate of what the patient ought to accept, try that glass, and then the glasses on either side of it, that is, weaker and stronger glasses, and ask the patient this question, which do you prefer? If you satisfy your patient you are correct. If you do not satisfy him you need not be wrong, for there are some people who

cannot be made to say that they are satisfied, and, moreover, the case may be complicated. Do not try to force a glass upon a person because your science tells you it is the correct glass. Common sense should be your guide as much as science.

CHAPTER IX.

MYDRIATICS.

Mydriatics are used for the purpose of paralyzing the accommodation with a view to discovering the true condition of the refraction. In hypermetropia and myopia there is probably a tonic contraction of the ciliary muscle which is not altogether lost till advanced age. There is also an excessive contraction of the ciliary muscle which is known as spasm of the accommodation, and renders emmetropes myopic, hypermetropes less hyperopic, and myopes more myopic. The action of the mydriatic by eliminating the action of the muscle, enables us to judge of the true refractive power of the eye.

Spasm occurs in cases in which the eyes have been strained by excessive use, either for distance or near, but more frequently for the latter, and is evidenced in the functional examination by alternate or irregular clearness and dimness of the letters and by the contradictory or uncertain answers of the patient when glasses are put before the eye. Headache almost invariably accompanies this condition whatever may be the refractive state.

The two agents for paralyzing the accommodation are homatropine hydrobromate and atropine sulphate.

Homatropine hydrobromate is a derivative of atropine and its effects are more transient than those of atropine sulphate. The length of the duration of either depends, in a measure, on the strength of the solution. Homatropine

is made into a 1%, 2% or 3% solution; that is, roughly speaking, 5 grains, 10 grains or 15 grains to the ounce. For my part, I never use a greater strength than a 2% solution. The 3% solution causes the eye to be red and congested if rapidly instilled. The redness, however, disappears after a short while.

The frequency of the instillations is a matter of some importance. In adults six or eight instillations of one or two drops each may be used. But in children it is well to be more careful, although I can record no case of toxic symptoms among them from the use of homatropine. Let the solutions be made up with a few grains of boric acid to keep them sweet. And do not prescribe a large amount when you prescribe it for home use. A one drachm solution is quite sufficient. For the drug is one of the most costly that exist. Let us write the formula for a two per cent. solution for office use:

℞ Homatropinæ hydrobromat.	grs. x.
Acidi borici	grs. x.
Aquæ dist.	ʒi.

Sig. 2% solution of Homatropine hydrobromate.

The effect of this solution lasts about 24 hours, and the maximum effect on the accommodation is 3 or 4 hours after the first instillation. It is not necessary, however, to wait for the maximum effect. When you find that the patient cannot read any of the type on either of the first two pages of the Jaeger Test, you may consider the accommodation fairly well eliminated. In cases in which the symptoms are not grave and the asthenopia is not complicated with other reflex symptoms, homatropine is satisfactory. In those cases, however, in which there are symptoms simulating some grave nervous disturbance, or in

which the headaches and eye-pains are extraordinarly severe, and particularly in the case of children with strabismus, atropine sulphate is preferable. The paralysis of the accommodation is more complete and lasting from this drug. Its duration is, on an average, a week—sometimes it is two weeks. I never use a stronger than a 1% solution for children. Care must be taken to watch for the point of toleration. Some children can stand an astonishing amount of atropine, and some exhibit toxic symptoms after one or two instillations. It is always well to caution the parents in regard to the possible effects, in order that they may not persist in the use of the drug after the appearance of toxic symptoms, and that they may not be frightened. An ordinary child can stand one drop in each eye 3 times a day. It is rare that toxic effects are seen in adults when atropine is used for the paralysis of the accommodation. A two per cent. solution is most satisfactory for this purpose.

℞ Atropinæ sulphat.	grs. x.
Acidi borici	grs. xv.
Aquæ dist.	℥i.

Sig. 2% solution of atropine sulphate.

Atropine may be kept in the eyes of children for months without the slightest evil result to the ultimate power of the accommodation. This is not the case in adults and old people.

It undoubtedly impairs the accommodation in both, and in old people particularly, when used for any length of time. The effect of both of these drugs is accelerated by combination with cocaine hydrochlorate in a 4% solution. For office work a mixture of cocaine and homatropine may be kept.

℞ Homatropinæ hydrobromat.	grs. v.
Cocainæ hydrochlor.	grs. x.
Acidi borici	grs. v.
Aquæ dist.	℥r.

Sig. 1 % Sol. of cocaine and homatropine.

The all important point to be settled is when the glasses should be prescribed—before the mydriatic, during its effect, or afterward. There is little doubt amongst authority that mydriatics were formerly more frequently prescribed than was necessary. More respect is now paid to the tonic contraction of the ciliary muscle than in the past. It is rare indeed that a hyperope in youth, even after the use of the mydriatic, shows the entire amount of his error. And it is not improbable that a myope possesses and retains a certain amount of tonic contraction of his ring muscle, thereby apparently increasing his myopia. Judgment and experience alone can direct you in the selection of cases in which mydriatics should be used. It is safe to say, however, that they are rarely, if ever, necessary after the age of forty. They may be used, broadly speaking, in youth, and when cases possess the symptoms of obscure nervous complaint; also, when the prescription of glasses, without their use, has failed to relieve the asthenopia. I do not see how any intelligent surgeon can prescribe glasses during the effect of the mydriatic, except in one class of cases, and that class is children, who have a high degree of hypermetropia and strabismus. In such cases, the total correction may be given while the eye is under the maximum effect of the drug, and the mydriatic may then be allowed to wear off gradually. If a child is very young, it will wear the glasses which were first given. If it is old enough to analyze its sensations, the glass, in

all probability, will have to be changed to one that is weaker after the mydriatic has disappeared. I do not recognize any other class in which the total correction, under a mydriatic, should be given. The examination should be made before the use of the mydriatic, during the height of its effect, and immediately after the effect has entirely worn off. If homatropine is used, three examinations are necessary for an intelligent knowledge of the refractive condition of the eye; if atropine sulphate is used, at least three examinations, probably more. Under all circumstances, the final examination should be made immediately after the mydriatic effects disappear. This is indicated, of course, by the patient's ability to read Jaeger No. 1 at the normal distance, if he be under the age of presbyopia. During the time the eyes are under examination, the patient should strictly abstain from their use for near work. The temptation for patients to use their eyes, particularly when the effect of the mydriatic has just worn off, is very great. This inclination should be resisted, for sometimes the eyes will relapse into the original condition of spasm, and the examination will have to be made again.

No. 1.—*Brilliant.*

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search of superfluities. Remote from polite, they still retained the primæval simplicity of manners; and frugal by habit, they scarce knew that temperance was a virtue. They wrought with cheerfulness on days of labor, but observed festivals as intervals of idleness and pleasure. They kept up the Christmas carol, sent true-love knots on Valentine morning, ate pancakes on Shrove-tide, showed their wit on the first of April, and religiously cracked nuts on Michaelmas-eve. Being apprised of our approach, the whole neighborhood came out to meet their minister, dressed in their fine clothes, and preceded by a pipe and tabor: a feast also was provided for our reception, at

No. 2.—*Pearl.*

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search of superfluities. Remote from polite, they still retained the primæval simplicity of manners; and frugal by habit, they scarce knew that temperance was a virtue. They wrought with cheerfulness on days of labor, but observed festivals as intervals of idleness and pleasure. They kept up the Christmas carol, sent true-love knots on Valentine morning, ate pancakes on Shrove-tide, showed their wit on the

No. 3.—*Nonpariel.*

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search of superfluities. Remote from polite, they still retained the primæval simplicity of manners; and frugal by habit, they scarce knew that temperance was a virtue. They wrought with cheerfulness on days of labor, but observed festivals as intervals of idleness and pleasure. They

No. 4.—*Minion.*

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search of superfluities. Remote from polite, they still retained the primæval simplicity of manners; and frugal by habit, they scarce knew that temperance was a virtue. They wrought with cheerfulness on days of labor, but observed festivals as

No. 5.—Bourgeois.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search of

No. 6.—Long Primer.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom visited towns or cities in search

No. 7.—Small Pica.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within themselves, they seldom

No. 8.—Pica.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the conveniences of life within

No. 9.—English.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As they had almost all the con-

No. 10.—Great Primer.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal strangers to opulence and poverty. As

No. 11.—Two-line Small Pica.

The place of our retreat was a little neighborhood, consisting of farmers, who tilled their own grounds, and were equal stran-

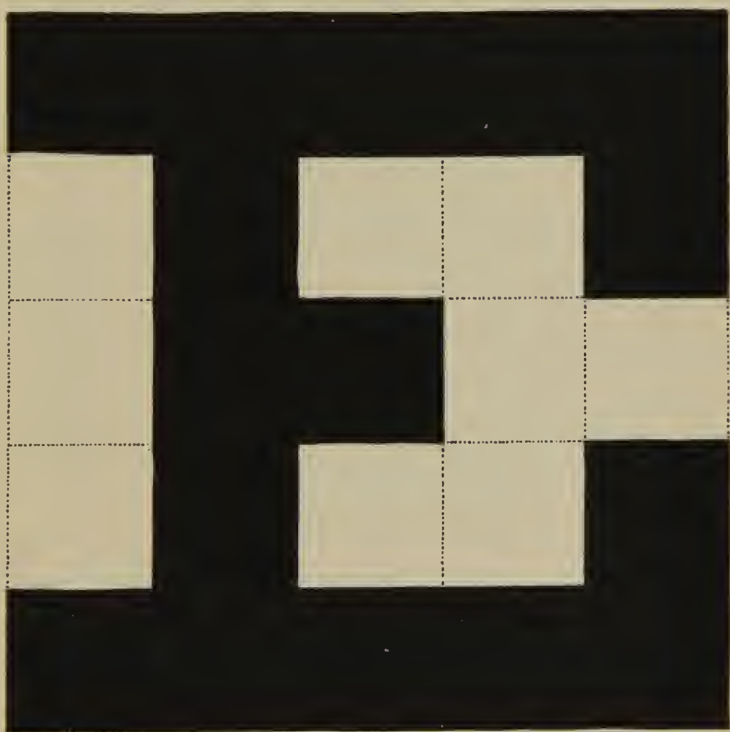
No. 12.—Two-line English.

The place of our retreat was a little neighbor-hood, consisting of far-mers, who tilled their

No. 13.—Two-line Great Primer.

The place of our retreat was a little neighborhood, consisting of far-

CC.



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XV.

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